

Transactions of the Royal Society of South Australia Incorporated

Contents

Milnes, A. R., Ludbrook, N. H., Lindsay, J. M. & Cooper, B. J.	The succession of Cainozoic marine sediments on Kangaroo Island, South Australia - - - - -	1
Ludbrook, N. H.	Molluscan faunas on the Early Pleistocene Point Ellen Formation and Burnham Limestone, South Australia - - - - -	37
Lansbury, I.	Notes on the Australasian species of <i>Cymatia</i> Flor s.l. (Insecta, Heteroptera: Corixidae) - - - - -	51
Skinner, S. & Womersley, H. B. S.	New records (possibly introductions) of <i>Striaria</i> , <i>Stictyosiphon</i> and <i>Arthrocladia</i> (Phaeophyta) for southern Australia - - - - -	59
Shepherd, S. A.	Benthic communities of upper Spencer Gulf, South Australia - - - - -	69
Davies, M., Martin, A. A. & Watson, G. F.	Redefinition of the <i>Litoria latopalmata</i> species group (Anura: Hylidae) - - - - -	87
Koste, W. & Shiel, R. J.	Morphology, systematics and ecology of new monogonont Rotifera (Rotatoria) from the Alligator Rivers region, Northern Territory - - - - -	109
Jell, P. A.	A larger bivalve arthropod from SADME Edeowie-1 well of probable Cambrian Age - - - - -	123
<i>Brief communications:</i>		
Lindsay, J. M.	Late Eocene to Late Oligocene age of the Kingscote Limestone, Kangaroo Island, S.A. - - - - -	127
Tyler, M. J.	<i>Neobatrachus sutor</i> Main: a frog new to the fauna of South Australia - - - - -	129
Tyler, M. J. & Anstis, M.	Replacement name for <i>Litoria glandulosa</i> Tyler & Anstis, 1975 (Anura: Hylidae) - - - - -	130
Jago, J. B. & Hilyard, D. B.	Comment: Late Precambrian-Cambrian stratigraphic nomenclature in the Adelaide Geosyncline - - - - -	131
Preiss, W. V.	Reply: Late Precambrian-Cambrian stratigraphic nomenclature in the Adelaide Geosyncline - - - - -	133
Glover, C. J. M.	Additions to the marine fish fauna of South Australia - - - - -	134
Lange, R. T.	Estimation of sheep stocking intensity at any location in arid zone paddocks - - - - -	137
Hutton, J. T.	Soluble ions in rainwater collected near Alice Springs, N.T., and their relation to locally derived atmospheric dust - - - - -	138

TRANSACTIONS OF THE

ROYAL SOCIETY OF SOUTH AUSTRALIA

INCORPORATED

VOL. 107, PART 1

TRANSACTIONS OF THE ROYAL SOCIETY OF SOUTH AUSTRALIA INC.

CONTENTS, VOL. 107, 1983

PARTS 1 & 2, 31 MAY

Milnes, A. R., Ludbrook, N. H., Lindsay, J. M. & Cooper, B. J.	The succession of Cainozoic marine sediments on Kangaroo Island, South Australia - - - - -	1
Ludbrook, N. H.	Molluscan faunas of the Early Pleistocene Point Ellen Formation and Burnham Limestone, South Australia - - -	37
Lansbury, I.	Notes on the Australasian species of <i>Cymatia</i> Flor s.l. (Insecta, Heteroptera: Corixidae) - - - - -	51
Skinner, S. & Womersley, H. B. S.	New records (possibly introductions) of <i>Striaria</i> , <i>Stictyosiphon</i> and <i>Arthrocladia</i> (Phaeophyta) for southern Australia - - - - -	59
Shepherd, S. A.	Benthic communities of upper Spencer Gulf, South Australia -	69
Davies, M., Martin, A. A. & Watson, G. F.	Redefinition of the <i>Litoria latopalmata</i> species group (Anura: Hylidae) - - - - -	87
Koste, W. & Shiel, R. J.	Morphology, systematics and ecology of new monogonont Rotifera (Rotatoria) from the Alligator Rivers region, Northern Territory - - - - -	109
Jell, P. A.	A larger bivalve arthropod from SADME Edeowie-1 well of probable Cambrian Age - - - - -	123
<i>Brief communications:</i>		
Lindsay, J. M.	Late Eocene to Late Oligocene age of the Kingscote Limestone, Kangaroo Island, S.A. - - - - -	127
Tyler, M. J.	<i>Neobatrachus sutor</i> Main: a frog new to the fauna of South Australia - - - - -	129
Tyler, M. J. & Anstis, M.	Replacement name for <i>Litoria glandulosa</i> Tyler & Anstis, 1975 (Anura: Hylidae) - - - - -	130
Jago, J. B. & Hilyard, D. B.	Comment: Late Precambrian-Cambrian stratigraphic nomenclature in the Adelaide Geosyncline - - - - -	131
Preiss, W. V.	Reply: Late Precambrian-Cambrian stratigraphic nomenclature in the Adelaide Geosyncline - - - - -	133
Glover, C. J. M.	Additions to the marine fish fauna of South Australia - -	134
Lange, R. T.	Estimation of sheep stocking intensity at any location in arid zone paddocks - - - - -	137
Hutton, J. T.	Soluble ions in rainwater collected near Alice Springs, N.T., and their relation to locally derived atmospheric dust - -	138

PARTS 3 & 4, 30 NOVEMBER

Barker, S.	New synonyms and new species of <i>Stigmodera</i> (<i>Castiarina</i>) (Coleoptera: Buprestidae) - - - - -	139
Plummer, P. S.	Correlation of the uppermost Late Precambrian Succession across the Torrens Hinge Zone in the Port Augusta region of South Australia - - - - -	171
Slansky, E.	Halloysite in a weathered profile at Port Macquarie, New South Wales - - - - -	177
Kailola, P. J.	<i>Arius graeffei</i> and <i>Arius armiger</i> : valid names for two common species of Australo-Papuan fork-tailed catfishes (Pisces, Ariidae) - - - - -	187
Banks, C. B., Birkett, J. R., Dunn, R. W. & Martin, A. A.	Development of <i>Litoria infrafrenata</i> (Anura: Hylidae) - - - - -	197
Shepley, E. A. & Womersley, H. B. S.	The Dumontiaceae (Cryptonemiales: Rhodophyta) of southern Australia - - - - -	201
Dulhunty, J. A.	Lunettes of Lake Eyre North, South Australia - - - - -	219
Skinner, S.	Some freshwater Chlorophyta from the Bool Lagoon system in south-eastern South Australia - - - - -	223
Harvey, C.	A new species of <i>Nephurus</i> (Reptilia: Gekkonidae) from South Australia - - - - -	231
Tyler, M. J., Davies, M. & Martin, A. A.	The frog fauna of the Barkly Tableland, Northern Territory - - - - -	237
Tyler, M. J., Watson, G. F. & Davies, M.	Additions to the frog fauna of the Northern Territory - - - - -	243
<i>Brief communications:</i>		
Mawson, P. M.	On the status of some nematode species from Australian birds - - - - -	247
Riley, G. G., Milnes, A. R. & Bourman, R. P.	Landscape models for earth science research - - - - -	249
Wright, M. J.	Red-brown hardpans and associated soils in Australia - - - - -	252

THE SUCCESSION OF CAINOZOIC MARINE SEDIMENTS ON KANGAROO ISLAND, SOUTH AUSTRALIA

BY A. R. MILNES, N. H. LUDBROOK, J. M. LINDSAY & B. J. COOPER

Summary

Kangaroo Island has a more complete, although discontinuous, sequence of Cainozoic marine sediments than has been formerly recognised. Upper units of the predominantly Late Eocene bryozoal limestones at Kingscote are shown to be of Oligocene age. The wide occurrence of Miocene limestones is indicated by isolated outcrop remnants and by the inclusion of Miocene clasts in aeolian calcarenite and calcrete. The presence of Early Pliocene as well as Late Pliocene sandy limestones and calcareous sandstones is recognised for the first time. Richly fossiliferous limestones at Port Ellen, near Point Reynolds, and at Cape Willoughby are shown to be of Early Pleistocene age. Late Pleistocene and Holocene sediments with abundant Mollusca are confined to lowland areas adjacent to the present coastline.

THE SUCCESSION OF CAINOZOIC MARINE SEDIMENTS ON KANGAROO ISLAND, SOUTH AUSTRALIA

by A. R. MILNES*, N. H. LUDBROOK†, J. M. LINDSAY† & B. J. COOPER‡

Summary

MILNES, A. R., LUDBROOK, N. H., LINDSAY, J. M. & COOPER, B. J. (1983) The succession of Cainozoic marine sediments on Kangaroo Island, South Australia. *Trans. R. Soc. S. Aust.* **107**(1), 1-35, 31 May, 1983.

Kangaroo Island has a more complete, although discontinuous, sequence of Cainozoic marine sediments than has been formerly recognised. Upper units of the predominantly Late Eocene bryozoal limestones at Kingscote are shown to be of Oligocene age. The wide occurrence of Miocene limestones is indicated by isolated outcrop remnants and by the inclusion of Miocene clasts in aeolian calcarenite and calcrete. The presence of Early Pliocene as well as Late Pliocene sandy limestones and calcareous sandstones is recognised for the first time. Richly fossiliferous limestones at Point Ellen, near Point Reynolds, and at Cape Willoughby are shown to be of Early Pleistocene age. Late Pleistocene and Holocene sediments with abundant Mollusca are confined to lowland areas adjacent to the present coastline.

Two new formations are named and described: the Eocene-Oligocene Kingscote Limestone, and the Early Pleistocene Point Ellen Formation.

The occurrence of the Cainozoic limestones at various elevations and their ages as determined from palaeontological data provide the framework for an interpretation of the geological history of the Island, and a basis for understanding landscape development and soil formation. Evidence for encroachment of the Late Eocene to Middle Oligocene seas is not found far beyond the modern coasts of Kangaroo Island. At that time, the Jurassic Wisanger Basalt was exposed to erosion in adjacent lands and shed clasts into the marine environment. A major transgression in the Early Miocene resulted in widespread deposition of shallow marine limestones, even on parts of the plateau province presently at elevations in excess of 100 m. Following regression of the seas in the Middle Miocene, extensive weathering, erosion, and reworking of these limestones was initiated. Much of the carbonate in the calcretes that occur at high levels in the present landscape as duricrusts on relict landsurfaces as well as accumulation horizons within soil profiles may have been released to the regolith from the Miocene sediments at this time.

The seas again advanced onto the margins of Kangaroo Island in the Early Pliocene and had extended into low inland areas by the Late Pliocene, depositing shallow-water shelly limestones. Early Pleistocene marine sediments along the southern coast are overlain by thick aeolian carbonate sediments referred to the Bridgewater Formation. Complex calcrete profiles on these deposits signify an important hiatus and erosional break probably corresponding with uplift along the Cygnet Fault in the Middle Pleistocene.

Late Pleistocene beach deposits are recognised widely, and suffered reworking and impregnation by secondary carbonate following a lowering of sea-level prior to advance of the Holocene seas.

KEY WORDS: Kangaroo Island, Cainozoic, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, Holocene, Kingscote Limestone, Point Ellen Formation, landscape development, calcretes.

Introduction

Research on the origin and development of surficial terrestrial carbonate accumulations (calcretes) has concentrated on broad areas in southern Australia where their widespread distribution can be explained broadly in terms of (a) climatic regime, since carbonates are most likely to survive in semi-arid landscapes where leaching is not a dominant factor; and (b)

the proximity and availability of long-term sources of carbonate (Milnes & Hutton 1983). In fact, the main sources of secondary calcium carbonate in southern Australia have been fossiliferous Cainozoic marine limestones, and extensive strandlines of Late Cainozoic bioclastic beach and dune sands, both of which flank the modern coast.

On Kangaroo Island, calcretes are distributed throughout the landscape at elevations ranging from present sea-level to the high plateau, more than 120 m above sea-level. Careful examination of many outcrops has re-

* CSIRO Division of Soils, Private Bag No. 2, Glen Osmond, S. Aust. 5064.

† Department of Mines & Energy, P.O. Box 151, Eastwood, S. Aust. 5063.

vealed fossiliferous Cainozoic marine limestones which constitute the parent material. These provided the source for the calcium carbonate which, during exposure, weathering and erosion of the limestone, was mobilised and reprecipitated as secondary carbonate infillings, laminated crusts and rinds on clasts that are characteristic of calcrete deposits. In many cases, the calcretes display evidence of a complex history involving many phases of construction and degradation. Nevertheless, it is parent limestone which provides clues to the chronology of landscape development and the formation of the calcretes.

Little is known in any detail of the Cainozoic geology of Kangaroo Island, although parts of the fossiliferous succession were briefly described as early as 1816 by Peron and 1883 by Tate. This is largely due to the sporadic and obscure nature of the outcrops and the almost complete absence of sequential sections. The Island is essentially a southwestward extension of Fleurieu Peninsula in the southern part of the Delamerian (Early Palaeozoic) fold belt forming the Mount Lofty Ranges. The region has also been referred to as the Kangaroo Island-Fleurieu Peninsula elevated zone (Glaessner & Wade 1958). The nature of the basement west and south of the Island is not yet fully known (Ludbrook 1980, Fig. 1; Gerdes 1982). During the Cainozoic, uplift of the Mount Lofty Ranges by block-faulting and tilting positioned the Island medially between three major marine basins: the St Vincent Basin, the Murray Basin and the Duntroon Embayment of the Great Australian Bight Basin. As a consequence, Kangaroo Island received a succession of marine sediments from the Late Eocene onwards. Erosion throughout the Cainozoic removed much of the record, which has to be deduced from thin remnants, floaters in fields, inclusions in younger sediments or even calcrete, and to some extent from boreholes.

Though sparse and nowhere stratigraphically continuous, the sediments are significantly more extensive and together represent a more complete Cainozoic succession than has been recognised. They occur mostly as outcrop remnants at various levels in the landscape and also in the subsurface.

In this paper, the field relationships, distribution, lithology and palaeontology of many outcrops are considered, together with data for material available from boreholes. Although

it is clear from field and laboratory studies that our knowledge of the Cainozoic geology of the Island is still incomplete, we have assembled sufficient data on the fossil content and ages of the sediments to enable us to outline a succession of both Tertiary and Quaternary marine sediments which can be correlated with sequences in adjacent basins in southern Australia. Moreover, our data provide the framework for an interpretation of the geological history of Kangaroo Island through the Cainozoic, and a basis for examining the development of the contemporary landscape and soils.

Palaeontological data are based principally on studies of the Foraminifera and Mollusca. Foraminifera have been relied upon almost entirely to date Palaeogene strata, Foraminifera and Mollusca the Miocene and Early Pliocene, and Mollusca the Late Pliocene and Quaternary. The foraminiferal sequence is set out in Table 1, and that of the Mollusca in Table 2.

Apart from thin sections, all material used in the study is held in either the Geological Survey of South Australia (GSSA) Palaeontological Collection, or the CSIRO Division of Soils. Thin sections prefixed M are held by CSIRO Division of Soils, and those prefixed P by Australian Mineral Development Laboratories.

Previous studies

The establishment of a Cainozoic succession on Kangaroo Island has proceeded sporadically in three principal stages, the first two of which were concerned largely with observations on the bryozoal limestones exposed in the coastal cliffs at Kingscote. Contributors to the first stage were Tate (1883), Howchin (1899, 1903), and Chapman (1915) who relied mainly on echinoids to determine the age and correlation of the limestones. In the second stage, a significant step forward was made with the publication of a series of papers between 1955 and 1959 by Glaessner, Wade, and Carter, using foraminifera as a means of correlating the limestones with similar marine sediments in the St Vincent Basin. During the third stage from 1959 to the present, aided by more extensive collecting over much of the eastern part of the Island, a Neogene and Quaternary succession has emerged. Unfortunately, the work of Bauer (1959) was not published: the material referred to in his thesis has been recollected and reassessed.

TABLE 1. Stratigraphic ranges of selected foraminifera, Kangaroo Island.

FORAMINIFERA	LATE (but not latest) EOCENE	Latest EOCENE to MIDDLE Oligocene	Early LATE Oligocene	Late EARLY to MIDDLE MIOCENE	EARLY Pliocene	LATE Pliocene	QUATERNARY
<i>Chiloguembelina cubensis</i> (Palmer)							
<i>Globigerinatheka index</i> (Finlay)							
<i>Subbotina angiporoides</i> (Hornibrook)							
<i>Subbotina linaperta</i> (Finlay)							
<i>Subbotina</i> sp. ex gr. <i>S. angiporoides</i> - <i>S. linaperta</i>							
<i>Tenuitella gemma</i> (Jenkins)		-----					
<i>Tenuitella insolita</i> (Jenkins)							
<i>Turborotalia opima nana</i> (Bolli)							
<i>Asterigerina adelaidensis</i> (Howchin)							
<i>Asterigerina</i> sp. cf. <i>A. cyclops</i> Dorreen							
<i>Asterigerina</i> sp. cf. <i>A. waiareka</i> Finlay							
<i>Crespinina kingscotensis</i> Wade							
<i>Globorosalina westraliensis</i> Quilty							
<i>Halkyardia bartrumi</i> Parr							
<i>Linderina glaessneri</i> Quilty							
<i>Maslinella chapmani</i> Glaessner & Wade							
<i>Planolinderina johannae</i> (Carter)							
<i>Pseudopolymorphina</i> sp. cf. <i>P. carteri</i> Quilty							
<i>Quasibolivina taylori</i> Quilty							
<i>Reussella finlayi</i> Dorreen							
<i>Sherbornina atkinsoni</i> Chapman							
<i>Wadella hamiltonensis</i> (Glaessner & Wade)							
<i>Dimorphina janjukensis</i> Crespin							
<i>Massilina torquayensis</i> (Chapman)							
<i>Textularia</i> sp. cf. <i>T. cuspis</i> Finlay							
<i>Textularia</i> sp. cf. <i>T. marsdeni</i> Finlay							
<i>Guembelitra samuelli</i> Jenkins							
<i>Tenuitella munda</i> (Jenkins)							
<i>Amphistegina</i> sp.							
<i>Crespinella umbonifera</i> (Howchin & Parr)							
<i>Elphidium chapmani</i> Cushman							
<i>Elphidium crassatum</i> Cushman							
<i>Marginopora vertebralis</i> Blainville							
<i>Pararotalia hamiltonensis</i> (Parr)							
<i>Ammonia breccarii</i> (Linné)							
<i>Elbicides cynnorum</i> Carter							
<i>Elphidium rotatum</i> Howchin & Parr							
<i>Fabularia howchini</i> Schlumberger							
<i>Naturotalia clathrata</i> (Brady)							
<i>Polymorphina</i> sp. cf. <i>P. myrae</i> Parr & Collins							
<i>Elphidium</i> sp. cf. <i>E. crispum</i> (Linné)							
<i>Elphidium</i> sp. cf. <i>E. adelaidense</i> Howchin & Parr							

TABLE 2. *Distribution of Late Cainozoic fossil molluscs.*

	Early Pliocene	Late Pliocene	Early Pleistocene	Late Pleistocene	Holocene
BIVALVIA					
ARCIDAE					
<i>Anadara trapezia</i> Deshayes				X	
<i>Barbatia pistachia</i> Lamarck				X	
<i>Barbatia</i> sp.		X			
CUCULLAEIDAE					
<i>Cucullaea praelonga</i> Singleton		X			
GLYCYMERIDAE					
<i>Glycymeris</i> sp.		X			
<i>Glycymeris (Tucetilla) radians</i> (Lamarck)			X		
<i>G. (Tucetona) convexa</i> (Tate)			X		
<i>G. (Veletuceta) pseudaustralis</i> Singleton		X	X		
MYTILIDAE					
<i>Brachidontes erosus</i> (Lamarck)				X	X
<i>B. (Austromytilus) rostratus</i> (Dunker)				X	X
ISOGNOMONIDAE					
<i>Isognomon</i> sp.		X			
PECTINIDAE					
<i>Pecten benedictus albus</i> Tate				X	
<i>Chlamys (Chlamys) antiaustralis</i> (Tate)	X	X			
<i>C. (C.) asperima</i> (Lamarck)			X		
<i>C. (C.) asperima dennanti</i> Gatliff & Singleton			X		
<i>C. (Equichlamys) bifrons</i> (Lamarck)					X
<i>C. (E.) consobrina</i> (Tate)		X			
<i>C. (E.) palmipes</i> (Tate)		X			
SPONDYLIDAE					
<i>Spondylus spondyloides</i> (Tate)		X			
OSTREIDAE					
<i>Ostrea angasi</i> Sowerby				X	
<i>Ostrea</i> sp.	X	X			
<i>Ostrea</i> sp.			X		
LUCINIDAE					
<i>Wallucina assimilis</i> (Angas)				X	
<i>Callucina lacteola</i> (Tate)			X		
<i>Loripes</i> sp.			X	X	X
<i>Gibbolucina (Gibbolucina) salebrosa</i> (Woods)		X			
<i>Anodontia sphericula</i> (Basedow)		X	X		
<i>Linga (Bellucina) sp. nov.</i>			X		
<i>Divalucina cumingi</i> (Adams & Angas)		X			
<i>Miltha hamptonensis</i> Ludbrook		X	X		
ERYCINIDAE					
<i>Melliteryx acupunctum</i> (Hedley & May)				X	
TRIGONIIDAE					
<i>Neotrigonia trua</i> Cotton		X			
CARDITIDAE					
<i>Pleuromeris</i> sp. cf. <i>P. subpecten</i> Ludbrook		X	X		
<i>Cardita subdeceptiva</i> Ludbrook		X	X		
CRASSATELLIDAE					
<i>Eucrassatella kingicoides</i> (Pritchard)		X			
CARDIIDAE					
<i>Acrosterigma praecygnorum</i> (Ludbrook)		X			
<i>Fulvia tenuicostata</i> (Lamarck)				X	
MACTRIDAE					
<i>Mactra</i> sp. cf. <i>M. pura</i> Deshayes			X		
<i>Mactra australis</i> Lamarck				X	
<i>Zenatia (Zenatiopsis) sp.</i>		X			
<i>Anapella cycladea</i> (Lamarck)		X		X	
<i>Spisula (Notospisula) trigonella</i> (Lamarck)					X
MESODESMATIDAE					
<i>Amesodesma angusta</i> (Reeve)			X	X	X
<i>A. cuneata</i> (Lamarck)			X	X	X
TELLINIDAE					
<i>Tellina</i> sp.			X		

TABLE 2—continued.

	Early Pliocene	Late Pliocene	Early Pleistocene	Late Pleistocene	Holocene
<i>Tellina (Pseudarcopagia) basedowi</i> (Tate)	X				
<i>T. (Macomona) deltoidalis</i> Lamarck				X	X
PSAMMOBIIDAE					
<i>Sanguinolaria (Psammotellina) biradiata</i> (Wood)				X	
<i>S. (P.) donacioides</i> (Reeve)				X	X
VENERIDAE					
<i>Katelysia peronii</i> (Lamarck)				X	X
<i>Katelysia rhytiphora</i> (Lamy)				X	X
<i>Katelysia scalarina</i> (Lamarck)			X	X	X
<i>Circe weedingi</i> Cotton				X	
<i>Eumarcia fumigata</i> (Sowerby)					X
<i>Timoclea (Veremolpa) kendricki</i> Ludbrook			X		
<i>Gafrarium perornatum</i> Woods			X		
CORBULIDAE					
<i>Corbula (Notocorbula) flindersi</i> Cotton				X	
CLEIDOTHAERIDAE					
<i>Cleidotherus albidus</i> (Lamarck)				X	
MYOCHAMIDAE					
<i>Myadora corrugata</i> Tate	X	X			
SCAPHOPODA					
DENTALIIDA					
<i>Dentalium latesulcatum</i> Tate		X	X		
GASTROPODA					
HALIOTIDAE					
<i>Haliotis (Exohaliotis) cyclobates</i> Peron & Lesueur			X		
<i>Haliotis (Padollus) scalaris</i> Leach				X	
FISSURELLIDAE					
<i>Clypidina (Montfortula) rugosa</i> (Quoy & Gaimard)			X		
PATELLIDAE					
<i>Patella (Scutellastra) laticostata</i> Blainville				X	
<i>Patella (Scutellastra) peronii</i> Blainville			X		
ACMAEIDAE					
<i>Patelloida nigrosulcata</i> (Reeve)			X	X	X
TROCHIDAE					
<i>Thalotia conica</i> (Gray)				X	
<i>Cantharidus (Phasianotrochus) eximius</i> (Perry)			X		
<i>C. (P.) irisodontes</i> (Quoy & Gaimard)				X	X
<i>Clanculus (Isoclanculus) dunkeri</i> (Koch)				X	
<i>Monodonta (Austrocochlea) constricta</i> Lamarck				X	X
<i>Calliostoma (Fautor) legrandi</i> (Tenison Woods)				X	
<i>Calliostoma (Salsipotens) armillatum</i> Wood		X			
<i>Diloma (Chlorodiloma) adelaidae</i> (Philippi)				X	
<i>Diloma (Fractarmilla) concamerata</i> (Wood)				X	
<i>D. (F.) rudis</i> (Gray)			X	X	
<i>Monilea euclensis</i> Ludbrook			X		
TURBINIDAE					
<i>Liotina (Munditia) hedleyi</i> (Pritchard & Gatliff)					X
<i>L. (M.) subquadrata</i> (Tenison Woods)				X	
<i>Astraea (Micastraea) aurea</i> (Jonas)			X	X	
<i>Astraea (Micastraea) rutidoloma</i> (Tate)			X		
<i>Turbo (Ninella) torquatus</i> Gmelin			X		
<i>Turbo (Subninella) undulatus</i> Solander				X	
NERITIDAE					
<i>Nerita</i> sp. nov.			X		
<i>Nerita (Melanerita) atramentosa</i> Reeve				X	
PHASIANELLIDAE					
<i>Phasianella australis</i> (Gmelin)		X	X	X	
<i>Phasianella angasi</i> Crosse			X	X	

TABLE 2—continued.

	Early Pliocene	Late Pliocene	Early Pleistocene	Late Pleistocene	Holocene
LITTORINIDAE					
<i>Littorina (Austrolittorina) unifasciata</i> Gray				X	
<i>Bembicium melanostoma</i> (Gmelin)			X	X	X
<i>Bembicium nanum</i> (Lamarck)			X	X	X
POMATIOPSIDAE					
<i>Coxiella striata</i> (Reeve)					X
TURRITELLIDAE					
<i>Gazameda adelaidensis</i> Cotton & Woods		X			
<i>Gazameda iredalei</i> Finlay			X	X	
POTAMIDIDAE					
<i>Batillaria (Batillariella) estuarina</i> (Tate)				X	
<i>Batillaria (Zeacumantus) diemenensis</i> (Quoy & Gaimard)			X	X	X
<i>Eubittium lawleyanum</i> (Crosse)				X	X
DIASTOMATIDAE					
<i>Diastoma adelaidense</i> Ludbrook		X			
<i>Diastoma melanioides</i> (Reeve)			X		
CERITHIIDAE					
<i>Diala lauta</i> A. Adams			X	X	X
<i>Bittium (Semibittium) granarium</i> Kicner				X	
<i>Campanile symbolicum</i> Iredale			X		
<i>Campanile triseriale</i> Basedow		X			
<i>Hypotrochus monachus</i> (Crosse & Fischer)				X	X
IANTHINIDAE					
<i>Hartungia dennanti chavani</i> Ludbrook			X		
<i>Hartungia dennanti dennanti</i> (Tate)	X				
CAPULIDAE					
<i>Capulus</i> sp.					X
HIPPONICIDAE					
<i>Hipponix (Sabia) conicus</i> (Schumacher)			X	X	
<i>Hipponix (Antisabia) erma</i> (Cotton)			X		
NATICIDAE					
<i>Polinices (Conuber) conicus</i> (Lamarck)			X	X	
<i>Sinum (Ectosinum) zonale</i> (Quoy & Gaimard)				X	
CYMATIIDAE					
<i>Cymatella gaimardi</i> Iredale				X	
<i>Cymatella verrucosa</i> (Reeve)			X		X
MURICIDAE					
<i>Bedeia paivae</i> (Crosse)				X	X
<i>Lepsiella flindersi</i> (Adams & Angas)				X	
<i>Thais orbita</i> (Gmelin)				X	
COLUMBELLIDAE					
<i>Mitrella acuminata</i> (Menke)				X	
<i>Mitrella (Dentimitrella) lincolnensis</i> (Reeve)				X	X
<i>Mitrella (Dentimitrella)</i> sp.				X	X
<i>Euplicia bidentata</i> (Sowerby)				X	
BUCCINIDAE					
<i>Cominella eburnea</i> (Reeve)			X		
<i>Cominella lineolata</i> (Lamarck)				X	
NASSARIIDAE					
<i>Niotha pauperata</i> (Lamarck)				X	X
<i>Niotha pyrrhus</i> (Menke)			X	X	X
FASCIOLARIIDAE					
<i>Propefusus undulatus</i> (Perry)				X	
<i>Fusinus australis</i> (Quoy & Gaimard)				X	
OLIVIDAE					
<i>Amalda (Gracilispira) monilifera</i> (Reeve)			X		
VOLUTIDAE					
<i>Amoria (Amoria) grayi</i> Ludbrook			X		X
<i>Ericusa</i> sp. cf. <i>E. ancilloides</i> (Tate)		X			
CANCELLARIIDAE					
<i>Sydaphera undulata</i> (Sowerby)			X		

TABLE 2—continued.

	Early Pliocene	Late Pliocene	Early Pleistocene	Late Pleistocene	Holocene
CONIDAE					
<i>Conus (Flerocynus) anemone</i> Lamarck				X	
<i>Conus</i> sp.			X		
BULLIDAE					
<i>Bulla botanica</i> Hedley				X	
SIPHONARIIDAE					
<i>Siphonaria (Hubendickula) haconii</i> Reeve			X	X	
AMPHIBOLIDAE					
<i>Salinator fragilis</i> (Lamarck)				X	X
ELIOLIIDAE					
<i>Mulinula xanthostoma</i> H. & A. Adams				X	

In the earliest reference to the geology of Kangaroo Island, Tate (1883) described a bryozoan limestone in cliff sections at Kingscote. He considered this to be of Miocene age from his identification of the echinoid *Echinolampas gambierensis* (a Miocene species) and by comparison with sediments of similar lithology at Stansbury on Yorke Peninsula.

From two visits to the Island, Howchin (1899, 1903) also described the limestones in the Kingscote cliffs and referred them to the Eocene based on the presence of several echinoid species including *Australanthus longianus* (then placed in *Cassidulus*), *Echinolampas posteroocrassa* and *Fibularia gregata*. He noted in 1903 that the limestone filled "eroded hollows in Permian glauconitic clays". A conglomerate about 1 m thick of rounded basalt clasts in a carbonate matrix containing fossil molluscs was seen to overlie the limestone at three to four metres above present sea level. Howchin regarded this as a stranded Recent coastline deposit.

In addition, Howchin discovered in 1899 an "inconspicuous outcrop of Eocene limestone" in section 317 hundred of Menzies, about 3.2 km southwest of Smith Bay, where fragments of the fossiliferous rock were scattered over the land surface. He also reported "Eocene limestone" cropping out in a cliff section south of the lighthouse at Cape Willoughby, and described this material as "sparingly fossiliferous", "greatly leached", and containing many granite boulders of varying sizes. Howchin considered that the widespread calcareous crust on the headland near the Cape was formed by reprecipitation of the carbonate dissolved from the limestone.

Arthur Wade (1915) made collections from the limestones at Kingscote, from a fossiliferous

limestone section up to four metres thick at Point Ellen on the southwestern side of Vivonne Bay, and from a locality near the mouth of the Eleanor River in Vivonne Bay. From a palaeontological examination of these samples, Chapman (1915) concurred with Tate's dating of the Kingscote material as Miocene, and identified, together with some minor elements, a number of echinoid species including *Echinolampas gambierensis*. Subsequent to his original paper, Tate (1891) recorded *Australanthus longianus* but did not confirm the occurrence of *E. gambierensis* at Kingscote, and, in fact, indirectly implied that he had misidentified the species. However, Chapman identified the species as occurring with *E. posteroocrassa* at Kingscote. Chapman's reference and material were both overlooked by McNamara & Philip (1980) in revising the genus *Echinolampas* in southern Australia.

Chapman's specimen labelled *Echinolampas gambierensis* is in the GSSA collection. Although the aboral surface is obscured by hard limestone matrix, the specimen can be confidently identified as a large example of *Echinolampas posteroocrassa posteroocrassa*. *E. gambierensis* should therefore be removed from lists of the echinoids occurring at Kingscote. Chapman compared the limestones at Kingscote with those at Mannum in the Murray Basin, and correlated the deposits at Point Ellen with rocks northwest of Yorketown on Yorke Peninsula, and at Hallett Cove. As beachrock sampled near the mouth of the Eleanor River contained mostly living mollusc species, it was regarded as Late Pleistocene or Holocene in age, similar to raised beaches in Victoria.

A paper on Tertiary sedimentation in southern Australia (Glaessner 1953) heralded a second generation of reports largely con-

cerned with foraminifera. Glaessner referred to *Australanthus longiaquus* as an important species in the fauna of the Late Eocene Tortachilla Limestone of the Adelaide region, and because of its common occurrence in the limestones at Kingscote, assigned these limestones to the Late Eocene.

Sprigg (1954) produced the first comprehensive geological map of Kangaroo Island, on which several outcrops of Tertiary limestones at Kingscote and in the tributaries of the Cygnet River and Gum Creek, on Cape Willoughby, and at Porky Flat, were assigned to the "Early Tertiary".

A distinctive new foraminiferal genus and species of the *Chapmanininae* (*Crespinina kingscotensis*) was described from Kingscote by Mary Wade (1955) who reported its wide geographical distribution and restricted stratigraphic range (Late Eocene in South Australia, Late Eocene to Early Oligocene in western Victoria). The species has not been found subsequently above the Eocene in South Australia, and on the basis, for example, of the distribution of *Globigerinatheka index*, it is also probable that the Victorian occurrences (up to basal Glen Aire Clay) are all Eocene. Mary Wade described the limestones at Kingscote as shallow water deposits composed mainly of Bryozoa and almost free of terrigenous material. Later, Wade & Carter (1957) described the foraminifer *Sherbornina crassata* present "with an Upper Eocene fauna" including *Crespinina kingscotensis* in the Kingscote section. A list of planktonic and benthonic foraminifera in the "Eocene of Kingscote" was published by Wade in 1964.

Glaessner & Wade (1958) discussed the Tertiary sediments on Kangaroo Island in relation to the Cainozoic St Vincent Basin. They suggested that the Kangaroo Island counterpart of the "Willunga Basin" was a small basin, referred to as the "Kingscote-Cygnet Basin", in which Tertiary sediments rested on Permian glauconitic sediments. The outcrops at Kingscote were reported to represent a more calcareous and bryozoal facies than the equivalent Eocene Tortachilla Limestone in the Adelaide region. Bryozoal limestones of Oligocene-Miocene age were stated to occur in the Kingscote-Cygnet Basin "in small outcrops above pre-Tertiary strata", as well as at "Cape Willoughby and in a few other places south of the Cygnet Scarp". Glaessner & Wade corre-

lated these sediments with the Manulim Formation and the Morgan Limestone of the Murray Basin, and the Gambier Limestone of the Otway Basin.

In a comprehensive thesis on the geography of Kangaroo Island, Bauer (1959) examined and collected samples from many outcrops of both Tertiary and Quaternary sediments. Although he regarded the limestones at Kingscote as Miocene in the text of his thesis, information given in appendices indicates that Mary Wade identified as Eocene the fauna of the samples which she examined. Additional studies attributed to Wade and Glaessner (*In* Bauer 1959) identified the limestones mapped by Sprigg (1954) along the Cygnet River and Gum Creek as Tertiary and Miocene-Pliocene respectively. Bauer, however, preferred a Pliocene age for these limestones, and cited similar sediments cropping out in the banks of an intermittent lagoon ("Kent Lagoon") in section 172 hundred of Haines, based on a palaeontological report by Cotton (*In* Bauer 1959). Bauer could not find Howchin's "Eocene limestone" at Cape Willoughby, but suggested that it might be Pliocene in keeping with the supposed age of the majority of Tertiary limestone outcrops on the Island. Glaessner (*In* Bauer 1959) identified the fauna in a sample of limestone from Porky Flat as indicative of a Miocene-Pliocene age, but Bauer referred to the material as Pliocene in the text of his thesis. Samples of calcareous sandstone from Kelly Hill Caves and Mount Taylor, along the South Coast Road, were examined by Chinner and Glaessner (*In* Bauer 1959) and identified as "shallow water marine limestones of Late Tertiary (probably late Pliocene) age".

Based on the molluscan fauna, Ludbrook (1959) referred the limestones cropping out in Gum Creek to the Pliocene. Subsequently, Ludbrook (1963) used foraminiferal correlations to establish equivalence with the Tortachilla Limestone of the Adelaide region and hence an Upper Eocene age for the limestones "at Kingscote and Cygnet River and at depth in the Hundred of Menzies on Kangaroo Island". The limestones located in outcrop in Gum Creek and at Point Reynolds were shown in the correlation table in her paper as Hallett Cove Sandstone equivalents of Upper Pliocene age. Later, Ludbrook (1969) assigned to the Eocene, as Tortachilla Limestone or its equivalent, subsurface sediments about 18 m thick

and resting on bedrock at about 52 m depth near Flour Cask Bay.

Bleys (1962) described the subsurface occurrence of fossiliferous Tertiary sediments from holes drilled between Pelican Lagoon and Flour Cask Bay during groundwater investigations on Kangaroo Island. He interpreted these deposits as evidence of an ancient strait separating Dudley Peninsula from the rest of the Island.

Cooper & Lindsay (1978) assumed that Kangaroo Island was largely emergent during the Cainozoic. They recognised the passage postulated by Bleys, and suggested that it facilitated marine entry into the St Vincent Basin during the Eocene, Pliocene and Quaternary. They based their discussion on the reported distribution of Late Eocene limestones and Pliocene sandstones in boreholes near Flour Cask Bay in close proximity to the low-lying neck of land between Dudley Peninsula and the main mass of the Island to the west, and in the nearby "Kingscote-Cygnets Embayment". However, their contention that the Late Eocene limestones in the "Kingscote-Cygnets Embayment" were "known to extend over the Cygnets Fault as far south as the southeast corner of section 1 hundred of Macgillivray" is not confirmed.

In a recent review, Daily *et al.* (1979) summarised much of the published data on the

geological history of Kangaroo Island. They referred to shallow, warm-water marine limestone sedimentation during the Eocene at Kingscote and in the Cygnets River area, and near Flour Cask Bay, with further marine deposition in the Oligocene-Miocene based on the occurrence of isolated exposure of limestones of this age reported by Glaessner & Wade (1958). They considered that, consistent with other parts of the St Vincent Basin, elevation and tilting of the southern part of the Island relative to the Nepean lowland along the Cygnets and Snelling Faults had taken place during the Middle Miocene. Subsequent marine deposition in the region was delayed until the Late Pliocene, when a widespread transgression deposited fossiliferous sediments, including Hallett Cove Sandstone equivalents, in warm, shallow seas that they believed inundated a large part of the Island. They suggested, further, that Kangaroo Island might have been uplifted as a whole during the Pleistocene when major uplift took place along the bounding faults of the Mount Lofty Ranges in the Adelaide region.

The Cainozoic Succession

Early Tertiary (Palaeogene) Period

Palaeocene to Middle Eocene

There are no known Palaeocene to Middle Eocene deposits on Kangaroo Island.

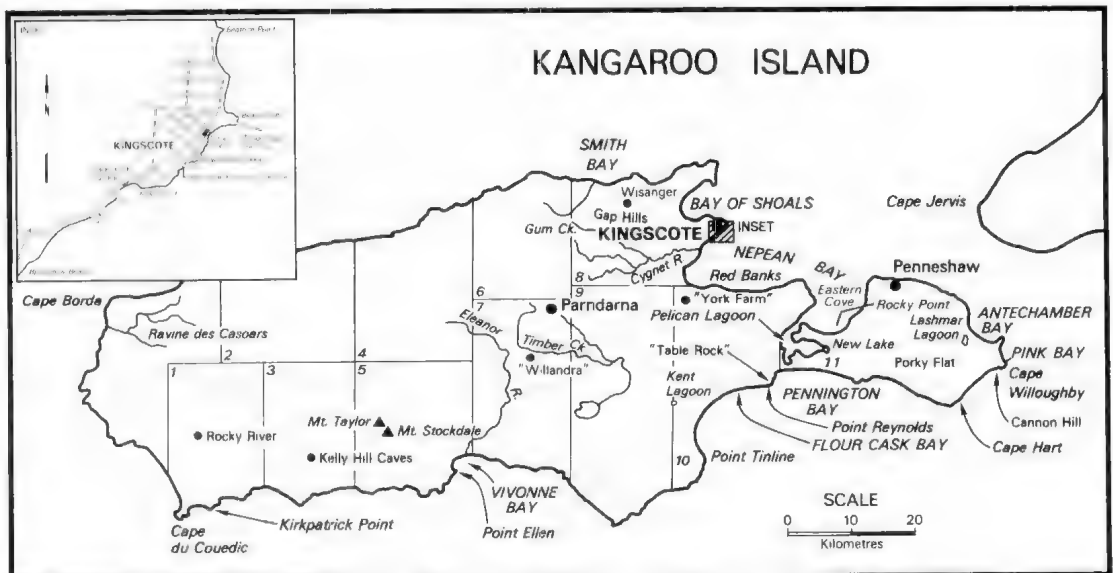


Fig. 1. Locality map. Key to Hundreds: 1—McDONALD, 2—GOSSE, 3—RITCHIE, 4—DUNCAN, 5—NEWLAND, 6—CASSINI, 7—SEDDON, 8—MENZIES, 9—MACGILLIVRAY, 10—HAINES, 11—DUDLEY.

Late Eocene to Oligocene

Fossiliferous marine sediments of Late Eocene age crop out in several localities. Their main distribution (Fig. 1) appears to be in the Nepean lowlands* at Kingscote and along the Cygnet River, and borehole data indicate that they also have a significant subsurface expression in this area. However, sediments of similar lithology and faunal composition crop out near Point Reynolds and are known from boreholes inland from Flour Cask Bay. Late Eocene bryozoal limestone is poorly exposed along Freestone Creek, south of Smith Bay. On present knowledge, the Late Eocene sediments occupy only low levels in the landscape and parts of the subsurface, but their widely scattered occurrence suggests a formerly extensive distribution and, accordingly, a high potential for the location of additional exposures as further work proceeds.

Foraminiferal faunas dated latest Eocene to Middle Oligocene, and Late Oligocene, have been found recently by one of us (Lindsay 1983) in the upper part of the Kingscote coastal section.

* Term used in the sense of Milnes *et al.* (1982).

- 1. Kingscote
- a. Kingscote Limestone. New stratigraphic unit.

The richly fossiliferous yellow to buff limestones exposed at Kingscote between the jetty at Beare Point and Brownlow Beach (Figs 2, 3) have never been formally designated as a stratigraphic unit distinct from the more



Fig. 2. Coastal cliffs southwest of swimming pool encompassing type section of Kingscote Limestone southwest of swimming pool. Late Eocene (beach level) and overlying Oligocene limestones dipping at shallow angle seawards.

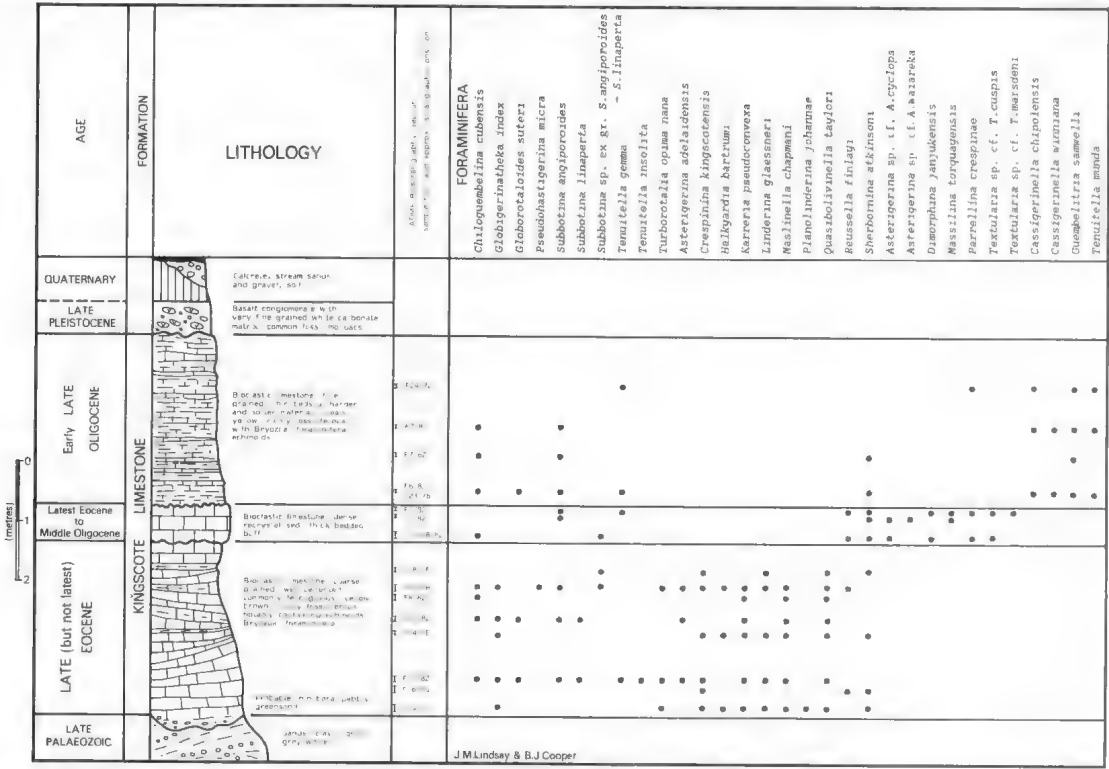


Fig. 3. Schematic composite columnar section and foraminiferal log of Kingscote Limestone outcrop between Beare Point and Brownlow Beach, Kingscote.

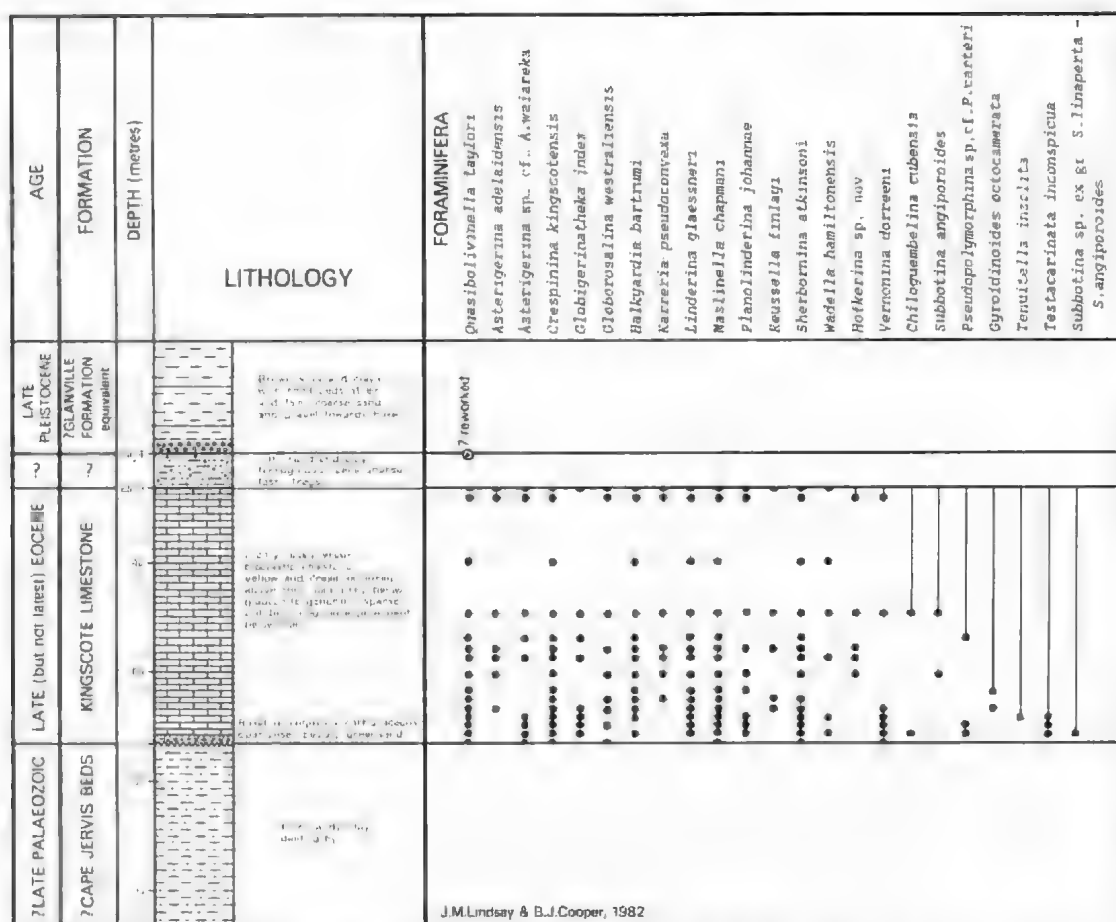


Fig. 4. Composite columnar section and foraminiferal log. E. & W.S. Pumphouse bore, Kingscote, 1962. (SADME Bore Unit No. 6426004WW00177).

continuous but partly time-correlative units exposed in Aldinga and Maslin Bays.

Reference sections: Typical Kingscote Limestone is exposed in the coastal cliffs and associated shore platforms at Kingscote, sections 406 and 407 hundred of Menzies; a measured type section is designated 150 m southwest of the swimming pool.

Another important section occurs at the base of cliffs at "Table Rock" near Point Reynolds, section H hundred of Haines, but it is difficult of access except at low tide.

Important subsurface sections of Kingscote Limestone were penetrated by the E. & W.S. Dept Pumphouse bore (Fig. 4), drilled in 1962 6 km southwest of Kingscote (section 46 hundred of Menzies) and by the Engineer-in-Chief's Kingscote bore, drilled in 1909-10 1 km north of Beare Point (section J1 hundred of Menzies).

Lithology: Bioclastic limestone, with a thin basal bed of pebbly quartzose greensand (not exposed but penetrated in the Pumphouse bore).

Thickness: In the coastal exposures in the type section, 4.5 m; in the Kingscote bore, 25-30 m; in the Pumphouse bore, approximately 50 m.

Age: Late Eocene to Late Oligocene.

Distribution: On Kangaroo Island at Kingscote, Cygnet River, Freestone Creek and Point Reynolds. In addition, a succession comparable with the Eocene part of the Kingscote Limestone has been recognised in Beach Petroleum Troubridge Shoal No. 1 borehole between 229 m and 259 m (Ludbrook 1963; Stuart 1970).

The Kingscote section comprises three lithologically distinguishable units: the lowest con-

sisting of echinoid-rich limestones capped by a rubbly mollusc-rich conglomerate of Late Eocene age; an intermediate bioclastic limestone of latest Eocene to Middle Oligocene age; and an upper unit of well-bedded to flaggy and cross-bedded bioclastic limestones of Late Oligocene age. For practical purposes all are best included for the time being in the Kingscote Limestone. However, they have lithological and chronological counterparts in the Port Willunga Formation on the eastern side of Gulf St Vincent. The lowest unit of the Kingscote Limestone, of Late Eocene age, is on faunal evidence, a correlative of the Tortachilla Limestone and at least part of the Blanche Point Formation in the eastern St Vincent Basin; while in terms of units on eastern Yorke Peninsula (Stuart 1970) it correlates faunally with Mulooowurtie Formation, Throoka Silts, and perhaps the basal part of Rogue Formation. A summary of contributions to correlations within the St Vincent Basin was provided by Cooper (1979).

On the northern side of Beare Point, Permian (Permian-Carboniferous *auct.*: Cooper 1981) glaciogene sediments are exposed in shoreline cliffs that extend northwards to Beatrice Point where the sediments are overlain by the Jurassic Wisanger Basalt. However, the Kingscote bore, which was drilled close to the coast 1 km north of Beare Point, entered the Eocene unit of the Kingscote Limestone at a depth of 6.1 m and continued through it to a depth of at least 31.1 m before entering Permian blue-grey sandy clay. The contact between the glaciogene sediments and the Tertiary limestones on Beare Point or in the vicinity of the Kingscote bore is not exposed, but the general relationships suggest that the limestones cropping out in the coastal zone between Beare Point and Brownlow Beach and dipping shallowly seawards were deposited on an eroded surface in the glaciogene sediments, as Howchin (1903) proposed.

The Kingscote Limestone in the coastal cliffs comprises grain-supported bioclastic rocks (grainstones and packstones) containing abundant echinoids, bryozoans, foraminifera and, less commonly, molluscs. Brachiopods, ostracods, barnacle plates, and algal pellets occur more rarely. *Dileupa* worm-tubes are common in the lowest Late Eocene unit. For several hundred metres southwest of Beare Point, the sequence appears to face southwest such that the lowest unit crops out northeast

of the swimming pool and the upper beds southwest of this locality. However, in the vicinity of Rolls Point and at Brownlow Beach, the lowest beds crop out again. Thus, the Oligocene units appear to be confined to the cliff section roughly between the swimming pool and Rolls Point. Overall, only a restricted stratigraphic section is exposed due to broad warping and the generally shallow and seaward dip of the beds. The Oligocene units tend to be thinly bedded to flaggy, and cross-bedding is common; thick-bedded intervals occur in the Late Eocene unit. The composition of the faunal debris, the general lack of terigenous material, and the presence of cross-bedding suggest a shallow water marine environment distant from fluvial influence.

Between Beare Point and the swimming pool, the basal beds of the formation include poorly to moderately cemented, thick-bedded and usually coarse-grained, echinoid-rich packstones with some thinly bedded and laminated units. About 50 m northeast of the swimming pool, an orange-brown bed about 30 cm thick, usually well cemented though weathering to a rubbly character, and strongly ferruginised in parts, is visible in the cliffs. The overlying interval comprises thinly bedded packstones with a thick limestone bed evident in the cliff section. Coarse-scale cross-bedding and channeling is evident in places. Thick-bedded packstones containing abundant large echinoids or layers rich in echinoid debris, underlie the rubbly bed. Partings separating units 1 m or so thick appear to correspond to thin layers of grainstone composed of closely packed bioclasts without significant matrix. At beach level, the upper part of the rubbly bed contains abundant rounded clasts, up to 2 cm diameter, of weathered basalt, brown algal material, quartz, reworked limestone, and other material which is not easily identified. In contrast with the echinoid-rich limestones below, the bed contains abundant bivalves and bryozoans, many corals and small sponges, and rare gastropods. Its conglomeratic character records an interruption of the shallow marine shelf environment by the influx of much coarse terigenous debris of fluvial origin, and this was accompanied by a marked faunal change. The concentration of iron oxide and the dramatic change in lithological and faunal characters signifies an appreciable time break in the section prior to a return to the marine environment essentially free of terigenous

material in which the overlying limestones were deposited.

The basal echinoid-rich limestones contain a distinctive Late (but not latest) Eocene foraminiferal fauna which includes benthonic forms *Asterigerina adelaidensis*, *Crespinina kingscotensis*, *Halkyardia* sp. cf. *H. bartrumi*, *Linderina glaessneri*, *Maslinella chapmani*, *Quasibolivina taylori*, and *Wadella hamiltonensis*; together with occasional examples of the planktonic species *Globigerinatheka index* and *Turborotalia opima nana*, the latter probably no older than Late Eocene (Blow 1979; McGowran 1978). The beds immediately above the hiatus have a microfaunal composition consistent with the intermediate unit of the Kingscote Limestone. Thus, the lithological hiatus in this part of the section corresponds to the Late Eocene–Early Oligocene disconformity determined southwest of the swimming pool.

150 m southwest of the swimming pool, a dense, thick-bedded, buff packstone (Fig. 5)



Fig. 5. Thin section of packstone (Late Eocene) exposed at base of type section through Kingscote Limestone. Note abundant micritic carbonate matrix. Bar scale 1 mm.

which represents the Late Eocene unit described above occurs at the base of the cliff section nominated as the type section for the Kingscote Limestone. An eroded upper surface on this bed displays hollows and fissures infilled by dense, white packstone, thus marking a disconformity (Fig. 6). This intermediate white packstone of Kingscote Limestone is here approximately 0.9 m thick and contains the following more stratigraphically significant foraminifera (Lindsay 1983): small *Subbotina* sp. from the *S. linaperta*–*S. angiporoides* group, *Textularia* cf. *cuspidis*, *T.* cf. *marsdeni*, *Massilina torquayensis*, *Reussella finlayi*, and *Gyroidinoides* cf. *allani*. Just northeast of Rolls Point, this unit has a similar thickness and contains *Subbotina angiporoides*, *Massilina torquayensis*, *Gyroidinoides* cf. *allani*, and a population of *Asterigerina*, some *A.* cf. *waiareka* and a few *A.* cf. *cyclops*. An age of latest Eocene to Middle Oligocene is possible for these faunas, but an Early to Middle Oligocene age is considered most likely.

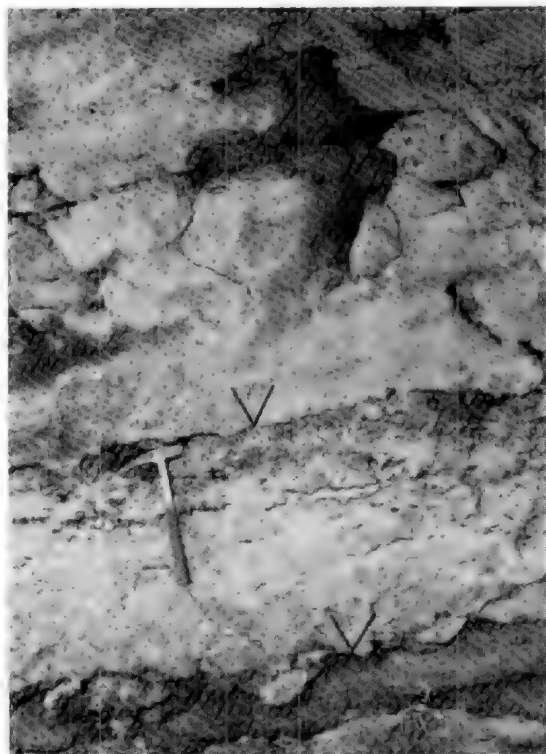


Fig. 6. Type section of Kingscote Limestone showing two disconformable surfaces (arrows) with hollows or channels infilled by overlying sediments. Late Eocene unit below lower surface; latest Eocene to Middle Oligocene unit between disconformities; Late Oligocene limestones above. Hammer 33 cm long.



Fig. 7. Type section of Kingscote Limestone showing thinly bedded Late Oligocene limestones above intermediate unit, with Late Eocene beds at base. Disconformities marked in ink. Hammer (encircled) 28 cm long.

At the type section, the upper surface of the intermediate white packstone also represents a disconformity, with hollows and irregularities infilled by a less consolidated, thinly bedded and cross-bedded packstone unit in which the harder bands have been accentuated by a preferential weathering of the softer layers (Fig. 7). This uppermost unit of the Kingscote Limestone is here about 2.8–3 m thick and continues to the top of the section where impregnation by secondary calcium carbonate has produced a calcrete crust. Five samples of this unit, collected between the swimming pool and Rolls Point have yielded stratigraphically useful microfaunas (Lindsay 1983). All contain *Guembelitria samwelli*, *Tenuitella munda*, and *Bolivina cubensis*, with *Chiloguembelina cubensis* in all but the stratigraphically highest (2 m above the disconformable base). *Subbotina angiporoides* occurs in three of the samples but not in the uppermost. *Tenuitella gemma* is present in two samples, including the uppermost. These foraminifera

date the unit Zone P.21, Middle to Late Oligocene.

The beds immediately below both disconformities weather to a distinct rubbly character, similar to that exhibited by the ferruginised conglomerate northeast of the swimming pool. In the type section, the lowermost disconformity forms the roof of a small sea-cave connecting with a large solution pipe that has developed through the limestones and extends to below present sea-level. Bedding in this locality dips approximately 15° to the southeast.

About 50 m to the southwest of the section, where the younger disconformity is just visible at beach level, the uppermost packstone unit (Middle to Late Oligocene) displays locally hardened thin beds and lenses, some of which have a red colour due to iron oxide impregnation. Conspicuous cross-bedding and channeling occur in the same unit approximately 20 m further southwest (Fig. 8). Large solution pipe and sinkhole structures lined with secondary calcium carbonate, and containing ferruginous pisolites in the mottled clay infill, are evident in the cliffs in this part of the section.

At Rolls Point in the vicinity of the Kingscote Yacht Club, an erosion surface marking a disconformity in the sequence appears as a rubbly-weathering, dense, pebbly limestone containing abundant molluscs including *Eotrigonia* and turritellids, and echinoids. With respect to its lithological and faunal composition, this bed is to be correlated with a similar bed marking the top of the Late Eocene unit northeast of the swimming pool and near the base of the reference section. Parts of the



Fig. 8. Cross-bedding and channeling in Late Oligocene thinly bedded limestones west of type section. Note thick-bedded and thin-bedded intervals. Hammer (encircled) 28 cm long.

beds below the rubbly limestone are rich in *Ditrupa* tubes and a variety of echinoids, but elements of the Eocene benthonic foraminiferal assemblage such as *Masthuella chapmani* and *Quastibolivinaella taylori* are only sparsely present. Buff-coloured packstones above the disconformity are well-bedded and form part of the intermediate unit of latest Eocene–Mid Oligocene age.

A little southwest of the Yacht Club, low outcrops of the Eocene unit of the Kingscote Limestone occur behind the beach and are intersected by abundant solution pipes filled with mottled brown clay. The beds are rich in small echinoids (*Fibularia gregata*), and contain less frequent larger echinoids including *Australanthus longianus*. The foraminiferal fauna includes the Late Eocene planktonic assemblage *Globigerinatheka index*, *Tenuitella insolita*, and *Subbotina limperia*, together with the Eocene benthonic species listed earlier. It is noteworthy that *Pseudopolymorphina carteri* has not yet been found either here or in other sampled exposures of this unit.

Outcrops of the Kingscote Limestone at Brownlow Beach comprise the type locality for *Crespinina kingscoteensis* Wade 1955. The southwesternmost exposures consist of cemented, dense, white to buff packstones with fluted and smoothed surfaces at beach level, but ragged and pitted surfaces above the waterline. The limestones are generally rich in molluscs. Some contain abundant clasts of quartz and feldspar of grit to small pebble size, and many rounded orange-brown algal pellets, which protrude from weathered surfaces. These beds comprise part of the lowest Late Eocene unit of the Kingscote Limestone. The numbers of rounded clasts of metasandstone and quartz scattered about the beach were probably derived from nearby Permian glaciogenic sediments, and may signify that the limestone beds are close to the base of the Tertiary sequence. Further to the northeast, however, outcrops of richly fossiliferous packstones and grainstones representing the same unit contain conspicuous small echinoids, echinoid spines, molluscs and bryozoans. The cliff section here is 3–4 m high, and bedding tends to be indistinct and rubbly in places.

2. Cygnet River

Late Eocene Kingscote Limestone is exposed beneath a thick calcrete crust in shallow quarries adjacent to the roadway between sections 47 and 62 hundred of Menzies in the

locality mapped by Sprigg (1954), but its field relationships are not evident. Mary Wade (reported by Bauer 1959) also recorded the limestone in section 44W, but this has not been confirmed by our field studies. The limestone is a coarse-grained, yellow-buff packstone containing abundant bryozoal, echinoid and foraminiferal debris. Algal pellets are common, but there are few quartz clasts and mollusc remains. Poorly preserved foraminifera have been recovered, including *Crespinina kingscoteensis*.

3. Freestone Creek

Just north of Smith Bay in section 317 hundred of Menzies, a coarse-grained recrystallised fossiliferous limestone crops out poorly on Freestone Creek. The limestone, discovered by Howchin (1899), is an eroded remnant exposed for about 200 m east of Freestone Creek as scattered "floors" on a low, calcrete-covered rise, and as surface floaters on another rise about 200 m further east. No field relationships are exposed, and the limestone was not intersected in bores drilled in adjacent sections 318 and 126. The only other record of the occurrence is contained in unpublished student field notes made in 1946 by W. R. Riedel and R. K. Johns. They described the limestone at the two localities along Freestone Creek. In places the limestone contains abundant grit-size clasts, as well as pebbles and cobbles up to 5 cm diameter, of quartz and bedrock. Molluscs are present, as reported by Riedel and Johns, and include large bivalves, not identified, *Chlamys slindersi*, and a cast of *Vulsella laevigata*. The microfauuna is identifiable from thin sections as of Eocene age, as Howchin determined. It includes abundant Bryozoa, with echinoid spines, algal pellets, and a few small molluscs and scattered foraminifera. The foraminifera are poorly preserved, but include *Halkyardia*, *Linderina*, and *Wadella hamiltonensis*. The lithology and faunal content permit correlation with the Late Eocene algal limestone with grit to pebble quartz clasts at Brownlow Beach.

4. Point Reynolds

Very little information has been published on this locality, and very little material has been systematically collected. The GSSA Collection contains two samples from a "Table Rock" locality in section H hundred of Haines. In an unpublished palaeontological report (F21/55), Ludbrook described one of the

samples as a "worn boulder of yellow bryozoal limestone with an echinoid fragment" of similar lithology to the Late Eocene limestones at Kingscote. The sample was reported to be typical of a lower horizon present at "Table Rock". The second sample was collected as typical of an upper horizon at the same locality, and was described by Ludbrook (F20/55) as "a worn boulder of white dense fossiliferous sandy algal limestone" of possible Pliocene age. On re-examination, this boulder has proved to have been derived from the Point Ellen Formation, of Early Pleistocene age.

The "Table Rock" locality is an embayment in the outcrops of Kanmantoo Group (Tapanappa Formation) bedrock forming the base of bold cliffs between Flour Cask Bay and Pennington Bay on the southeast coast of the Island. Point Reynolds is the southernmost part of the cliff-line. The locality is aptly named, for the Late Eocene and Pliocene limestones are horizontally bedded and form narrow platforms jutting out from the base of the cliffs into the sea (Figs 9, 10).

At the southwestern end of the embayment, thick-bedded, buff to yellow limestones containing abundant echinoids occur at sea-level near the base of the section (Fig. 11). The limestones can be disaggregated, yielding

abundant *Crespinina kingscotensis*, with *Halcyardia bartrumi*, *Linderina glaessneri* and *Maslinella chapmani*. *Chlamys aldingensis* and large oysters are present, and bryozoal remains and algal pellets are common. Contiguous outcrops of metasandstones striking ENE and dipping steeply southwards indicate that the Eocene sediments overlie an irregular erosional surface developed on the Kanmantoo Group, but the unconformity is not accessible for examination. The thickness of the Eocene limestones here is 3–3.5 m, but the local thickness will vary considerably depending on the relief on the unconformity.

The extent of the Tertiary sequence has not been investigated, but reconnaissance field observations and the presence of Eocene subsurface sections adjacent to Flour Cask Bay suggest that further outcrops may occur at sea-level along this comparatively little-known part of the coast.

5. Subsurface distribution

a. Nepean lowland

In the Nepean lowland immediately north of the Cygnet Fault, Eocene sediments similar to those that crop out at Kingscote and near Cygnet River have been intersected during drilling for groundwater and were described by Ludbrook (1969) as equivalents of the



Fig. 9. View of "Table Rock" locality near Point Reynolds, showing horizontally bedded Late Eocene and Pliocene limestones jutting out from base of cliffs. Dark reefs in left foreground and distance are Kanmantoo Group bedrock over which Cainozoic sediments unconformably lie. Height of cliffs 40–50 m.

Fig. 10. View looking southwest at "Table Rock" to section composed of Late Eocene limestones (E) overlain disconformably by Early and Late Pliocene (P) and Early Pleistocene (PI) sediments. Base of conglomerate marking disconformity highlighted. Early Pleistocene Point Ellen Formation forms flaggy beds underlying thick sequence of cross-bedded calcarenites of Bridgewater Formation.



Fig. 11. Thin section of Late Eocene limestone (M443) at base "Table Rock" section. Shows much biogenic debris (including *Crespina kingscotensis* near centre) and dark algal material, with rare quartz clasts. Bar scale 1 mm.

Tortachilla Limestone. Although approximately fifty boreholes have been drilled in the region, samples and/or geological notes have been retained from only a small number of holes, and currently Eocene strata have been determined from foraminifera recovered from only four of these. Nevertheless, the data suggest that a succession of fossiliferous sediments referred to the Kingscote Limestone underlies most of the region, and thickens eastwards towards Nepean Bay. Glaessner & Wade (1958) reported the presence of Oligocene-Miocene limestones as well as Late Eocene limestones here. However, only Late Eocene sediments were recognised by Ludbrook (1963, 1969), and with the notable exception of the newly-discovered Oligocene limestones in the Kingscote coastal cliffs, we have not so far been able to confirm the presence of Oligocene-Miocene deposits.

Yellow-brown, quartz sands and grits in Cygnet Park Ltd bore (section 34 hundred of Menzies) suggest littoral deposition in this area. Similar lithologies appear in bores from

section 288 hundred of Menzies, and section 38 hundred of Macgillivray. However, the thickest section of Kingscote Limestone (52 m of Late Eocene sediments) is that intersected in E. & W.S. Pumphouse bore No. 1 (Fig. 4), drilled on section 46 hundred of Menzies and completed in 1962. The Late Eocene section is approximately 50 m thick in this bore. Beneath 6 m of brown ferruginous silty and sandy clay with an occasional Eocene foraminifer (?reworked) and of doubtful correlation, most of the Eocene section consists of a bioclastic calcarenite almost identical with, but less cemented and weathered than, the coastal exposures. These carbonates are oxidised to a yellow-white colour in the top 31 m of the section, but are pale grey in the underlying 17 m. Rare sand-size quartz and more or less oxidised glauconite occur throughout. A thin interval of highly glauconitic, ferruginous, carbonaceous, quartzose greensand with an Eocene microfauna occurs immediately below the limestone. In this bore, the Kingscote Limestone unconformably overlies dark-grey sandy clays of presumably Permian age, and is overlain by Late Cainozoic deposits.

A rich fauna of well-preserved and diverse Late Eocene foraminifera occurs in the Pumphouse bore. The foraminifera are dominated by benthonic species and diagnostic Eocene species occur throughout the limestone interval (Fig. 4). These include: *Asterigerina adelaidensis*, *Crespina kingscotensis*, *Globigerinatheka index*, *Halkyardia bartrumi*, *Linderina glaessneri*, *Maslinella chapmani*, *Quasibolivina taylori* and *Wadella hamiltonensis*. *Wadella hamiltonensis* is not known to range higher than the Gull Rock Member of the Blanche Point Formation in the eastern St Vincent Basin, and *Asterigerina adelaidensis* does not range quite to the top of the Blanche Point Formation, but the other species continue into basal Port Willunga Formation. *Pseudopolymorphina* cf. *carteri* does not occur throughout the limestone interval in the Pumphouse bore. One fragment was found in the sample from 54.3–56.4 m; apart from that isolated occurrence it is present consistently but rarely between 70.1–73.2 m, i.e. near the base of the limestone section. Elsewhere in the St Vincent Basin, this form is found only in Tortachilla Limestone and basal Blanche Point Formation.

Thus, the foraminifera suggest that the Kingscote Limestone in the Pumphouse bore corre-

lates with the stratigraphic interval from Tortachilla Limestone or basal Blanche Point Formation up to about the top of the Gull Rock Member of Blanche Point Formation

b. Flour Cask Bay

Subsurface Tertiary sediments in the lowland area between Dudley Peninsula and the main mass of Kangaroo Island are best known to the west and north of Point Reynolds and adjacent to Flour Cask Bay (Ludbrook 1969) where drilling was carried out to assess local gypsum deposits, and to search for groundwater for washing gypsum. As at "Table Rock", the Late Eocene limestones are overlain by Pliocene sediments.

Bore records at the S.A. Department of Mines & Energy indicate the occurrence of Cainozoic limestones in twenty boreholes in sections 22, 25, 26, 42, 46, 47, 237, 262 and 288 hundred of Haines, and in sections 52, 55, 56, 312 and 318 hundred of Dudley. However, samples were available for study from only three holes in sections 22, 47 and 262 hundred of Haines. Late Eocene foraminifera are present in all three holes, but most occur together with Pliocene species and are therefore interpreted as reworked faunas. C.S.R. bore 19, drilled on section 22 hundred of Haines, less than 300 m from the coast adjacent to Flour Cask Bay, does include a distinguishable Late Eocene limestone. It underlies a sandy Pliocene sequence (of possible Early Pliocene age) which contains much reworked Eocene material. The borehole was certainly in Eocene limestone below a depth of 43.6 m, and the limestone rests with clear unconformity on Palaeozoic metasandstone at 53 m. Reworked Eocene foraminifera were found uphole to a depth of 19 m. The limestone is recrystallised, quartzose and sandy in part, and rich in Bryozoa and echinoids. A regressive, hard, calcareous, quartz sandstone is intercalated between 46.3–47.2 m. Glauconite occurs sparsely through most of the limestone, but is more abundant in the basal metre which is also ferruginous and quartzose. The limestone contains elements of the usual assemblage of Eocene benthonic foraminifera, viz. *Cresphidina*, *Halkyardia*, *Linderina*, *Mastrella*, and *Quasibolivina*. *Pseudopolymorphina* cf. *carteri* occurs only at the very base, suggesting a correlation of at least that horizon with Tortachilla Limestone and basal Blanche Point Formation. Tertiary sediments are not exposed on the coast at Flour Cask Bay, adjacent to

the gypsum lake, but selenites of the Bridgewater Formation crop out here.

c. Remarks

The Eocene megafaunas are dominated by echinoids, principally *Fibularia gregata*, *Australanthus longianus* and *Echinolampas posterocrassa*. Small brachiopods are not uncommon, including *Murrayia lenticularis*. The serpulid *Ditrupa* is abundant in places, and the bivalve *Chlamys aldingensis* is present.

Microfaunas include abundant bryozoal and echinoid fragments and the diagnostic foraminifera, mostly benthonic, noted above.

The Bryozoa have not been studied, but the assemblage contained in the Brownlow Beach fauna and revealed in thin sections of limestone from Freestone Creek and "Table Rock" includes some forms which appear to be diagnostic and in need of specialist examination.

Lithologically, the sediments represent deposition in shallow seas where there was generally a limited influx of terrigenous material. However, discrete disconformities within the Kingscote Limestone section record marked erosional influences with the introduction of sands and gravels, and are accompanied by faunal changes. The Late Eocene sequence was deposited widely around the present margins of the Island by seas which gradually encroached onto the Mesozoic to Middle Eocene landscape following the drifting apart of the Australian and Antarctic fragments of Gondwana. Late Eocene sediments equivalent to the Kingscote Limestone also occur in the Waitpinga Drainage Basin on the southern coastline of Fleurieu Peninsula (Bourman & Lindsay 1973). In the Murray and St Vincent Basins, and elsewhere in southern South Australia, non-marine sediments were deposited in lowland areas prior to encroachment of the seas (Ludbrook 1980), but these have not been recognised on Kangaroo Island.

Oligocene

As discussed above, the upper unit of the type section of Kingscote Limestone in the Kingscote cliffs contains a Late Oligocene foraminiferal fauna in the thinly bedded packstone unit forming the top of the section. This unit is separated from the latest Eocene to Middle Oligocene packstone immediately below by a disconformity, the uppermost of two unconformable surfaces recognised in the section.

The second disconformity separates the intermediate packstone unit from the underlying Late Pliocene limestones. Echinoids are not uncommon in the Oligocene beds and include *Mamantychia australis*. Previous records of echinoid species in the Kingscote Limestone should be viewed with caution as it is possible that some were collected from the Oligocene units. At this stage, the only Oligocene sediments known on Kangaroo Island are those described in the Kingscote cliffs section. They do not crop out near Point Reynolds where there is a major unconformity between the Late Eocene and Early Pliocene sediments. Of the two disconformities noted above, the upper is dated by foraminifera as occurring within Zone P21, Middle to Late Oligocene, which appears to correlate with a remarkable lowering of global sea-level at this time postulated by Vail *et al.* (Vail & Mitchum 1979; Vail & Hardenbol 1979). The lower disconformity is less firmly dated, but may correspond to the lesser fall in global sea-level postulated for the end of the Eocene by the same authors.

The geological history of the Island between deposition of the Late Oligocene phase of the Kingscote Limestone and various younger sediments ascribed generally to the Miocene is presently unknown. Sedimentation in the Adelaide region of the St Vincent Basin at this time is recorded within the Port Willunga Formation, which spans an interval from late in the Late Eocene to the Middle Miocene.

Neogene

Miocene

Limestones which are dated Miocene with varying degrees of confidence occur widely at high levels throughout the landscape on Kangaroo Island, ranging from isolated outcrop remnants 120 m above present sea-level south-east of Parndarna and in the southwestern part of the Island encompassed by Mounts Taylor and Stockdale and the region of Kelly Hill Caves, to broad terraces about 50 m above sea-level in the southeastern part of Dudley Peninsula. An even more extensive former distribution of these sediments is indicated by the occurrence of clasts of Miocene limestones reworked into the younger widespread veneers of aeolian calcarenite and calcrete that occupy much of the southern coastal regions of the Island.

1. Porky Flats

Porky Flats is a broad, closed depression in an extensive limestone terrain forming the southeastern part of Dudley Peninsula. This landscape is buttressed to the south around Cape Hart by cliffs of bedrock Kanmantoo Group Middleton Sandstone, but is open to the northeast into the lowlands around Lashmar Lagoon and Antechamber Bay. The Porky Flats fossil locality, recorded initially by Sprigg (1954) and later sampled by Bauer (1959), is a small dam excavation (originally a sink-hole) along the Cape Hart road in section 358 hundred of Dudley. Rocks cropping out here comprise fine-grained, consolidated, pink to white calcarenites containing bioclasts of foraminifera, small gastropods, bivalve, bryozoal and echinoid fragments, together with abundant well-sorted quartz clasts (Fig. 12). The local geology is dominated by humps and ridges of similar calcarenites, though much secondary calcrete is evident in places. Samples from the general region of the dam excavation, as well as approximately 2 km to the west near J. T. Howard's homestead and south-east along the Cape Hart road, also proved to be fine-grained calcarenites of Miocene age (Fig. 13). These rocks were mapped by Sprigg as consolidated dune limestone (aeolianite), and were referred to the Quaternary.

Seen in both random thin section and disaggregated residues, the limestones contain algal, echinoid, bryozoal and mollusc fragments, together with common benthonic foraminifera which are poorly preserved but include the species of *Pararotalia* from the Mannum Formation figured as *Rotalia* cf.



Fig. 12. Thin section of calcarenite (M253) from Porky Flats showing packstone fabric with well-sorted quartz clasts (white) and biogenic remains (mainly mollusc fragments) in dark micritic carbonate matrix. Bar scale 1 mm.

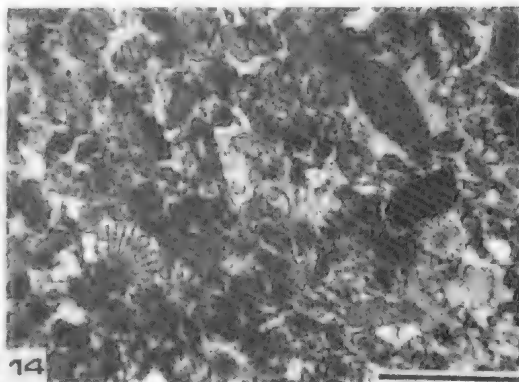
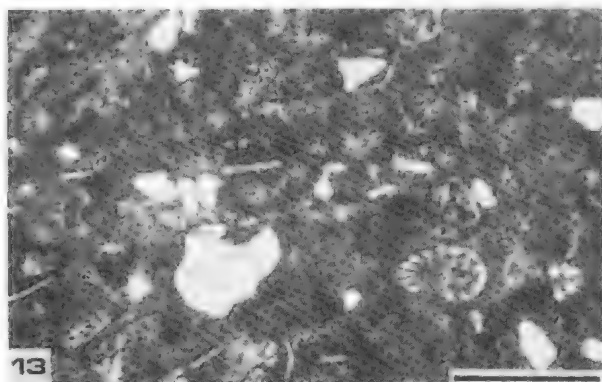


Fig. 13. Thin section of limestone M338B approaching wackestone fabric collected near Howard home-
stead west of Porky Flat dam excavation. Quartz clasts (white) and remains of bivalves, foraminifera
and echinoid spines are set in dark carbonate matrix. Bar scale 1 mm.

Fig. 14. Thin section of "Willandra" limestone M336A showing abundant biogenic remains including
dark algal fragments and echinoid spines. Some quartz clasts (white) and large calcite crystals
(grey; ?echinoid plates). Recrystallised calcite matrix. Bar scale 1 mm.

calcar (Ludbrook 1961, pl. 3, Figs 5, 6) which appears to be close to *Pararotalia hamiltonensis*, *Crespinella umbonifera*, *Discorbis* cf. *cycloclypeus*, *D.* cf. *balcombensis*, *D.* cf. *dimidiatus*, and *Elphidium crassatum*. In addition, Glaessner (*In* Bauer 1959) recorded *Marginopora* and *Amphistegina* from Porky Flat, although neither was seen in material collected from there for the present study, and the original samples are not available now for checking. Taken together, the most likely age is late Early Miocene to Middle Miocene, although *Pararotalia hamiltonensis* described from the Early Pliocene has not been recorded previously from strata older than possibly latest Miocene (Cheltenhamian Stage; Parr 1939). Stratigraphic overlap in the ranges of *Marginopora* and *Amphistegina* is known elsewhere in South Australia from subsurface upper Port Willunga Formation (Lindsay 1969), upper Melton Limestone (Lindsay 1970), and Morgan Limestone (Ludbrook 1961; Lindsay & Giles 1973).

2. "Willandra"

Fossiliferous limestones capped by calcrete occur about 10 km southeast of Parndarna on three small, low bedrock knolls, approximately 120 m above sea-level, south of Timber Creek on the properties "Willandra" and "Graydon". The outcrops appear to be within the dissected part of the laterite plateau, according to maps prepared by Bauer (1959). The bedrock knolls, composed of laminated and slump-bedded Kanmantoo Group metasandstones, are un-

altered residuals within the zone of deep weathering which is exposed in adjacent dam excavations. The limestones crop out poorly, but material collected by breaking up the calcrete crust includes recrystallised limestones and calcarenites. Recrystallised limestones near the eastern end of the middle knoll display karst features including fluted surfaces.

Although fossils are not always conspicuous in hand specimens, the limestones are seen in random thin section to contain abundant biogenic material including foraminifera and algal fragments (Fig. 14). The foraminifera include abundant *Pararotalia* sp. together with fragments of *Elphidium*, *Textularia*, miliolids and others, doubtfully identified, of general Miocene aspect. Silt-size quartz and clasts of metasandstone that occur in some samples record minor terrigenous influences in what were probably shallow seas in close proximity to a shoreline.

The ages of the limestones relative to deep weathering are not clear from the field relationships because of poor outcrop. However, it is possible that deep weathering pre-dated deposition of the limestones in the Miocene, and that Miocene seas were at least partly responsible for dissection of the main plateau, or that deep weathering post-dated deposition of the limestones, remnants of which were encased by calcrete and thus protected islands of bedrock from the major effects of weathering processes. The latter possibility is favoured because the limestones lack ferruginous detritus

or clays that could have been obtained from erosion of a lateritic terrain.

3. Southwestern Kangaroo Island

Mounts Stockdale and Taylor (section 31 hundred of Newland) are prominent outcrops of cemented calcarenite projecting above extensive sand plains. Mount Stockdale exhibits distinct weathering features including solution pipes, tafoni, gnammas and flared slopes (Fig. 15). In thin section, the grainstone contains abundant quartz fine-sand and biogenic remains in a much-recrystallised granular carbonate matrix (Fig. 16). Foraminifera, mollusc fragments and algal structures are common.

Similar calcarenites were collected from Kelly Hill Caves by Major & Vitols (1973). These are well-sorted, fine-grained rocks with some subangular-subrounded quartz clasts (Fig. 17) and abundant foraminifera including *Pararotalia* sp., *Elphidium chapmani* and *Crespinella umbonifera*, indicating a Miocene



Fig. 15. View of Mount Stockdale looking southwards. Limestone is cliff- and bluff-forming, with conspicuous solution features (for example along shallow-dipping joint plane), and flared slopes. Height of bluff left of centre approx. 12 m.

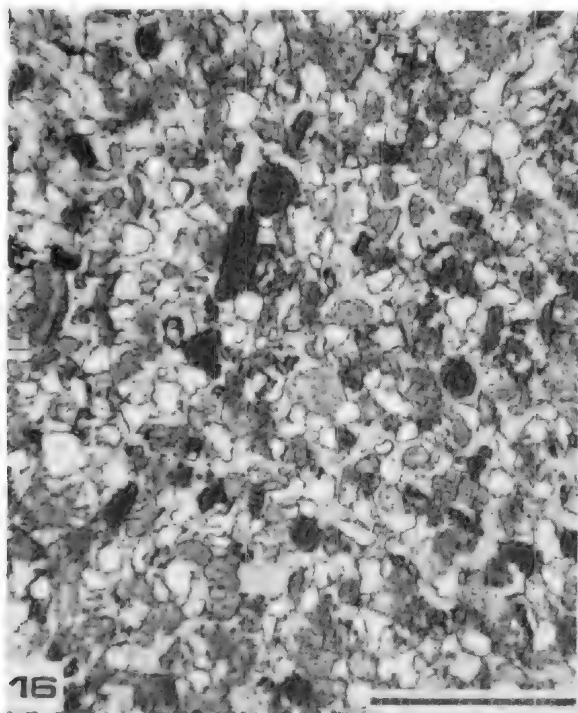


Fig. 16. Thin section of Mount Stockdale sandy limestone (M442) showing well-sorted quartz clasts (white), calcite grains (grey), and bioclasts of dark algal material and foraminifera. Bar scale 1 mm.

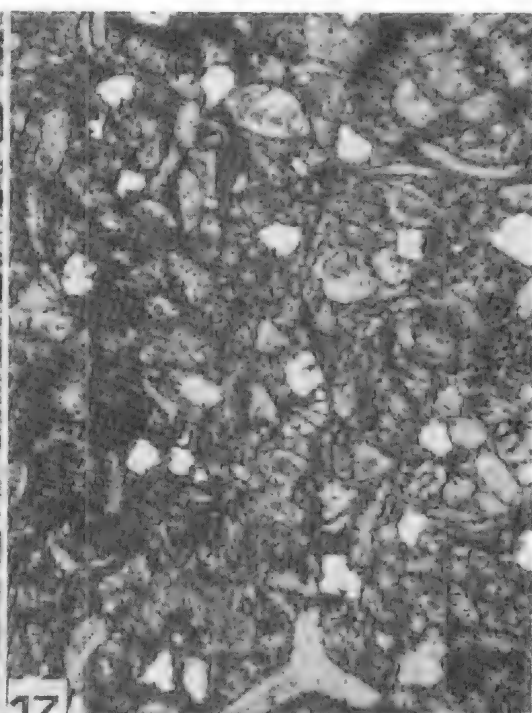


Fig. 17. Thin section of limestone P192/71 (Major & Vitols 1973) from Kelly Hill Caves. Much uniformly-sized bioclastic material (including foraminifera, mollusc fragments and sponge spicules), with some quartz clasts (white). Dark micritic carbonate in places probably of secondary origin.

age. In keeping with the conclusions of Bauer (1959), the outcrops at Kelly Hill Caves, Mount Taylor, and Mount Stockdale are to be regarded as primary marine sediments rather than Pleistocene aeolian deposits as mapped by Sprigg.

Further west at Kirkpatrick Point at the site of spectacularly weathered granite boulders locally named "Remarkable Rocks", clasts of dark-coloured, cemented grainstone containing Miocene foraminifera are present in palaeosols within a calcreted aeolianite complex unconformably overlying the Early Palaeozoic granite inselberg. Foraminifera in the clasts include *Crespinella umbonifera*, *Pararotalia* sp., *Cibicides refulgens*, and species of *Elphidium* related in *E. macellum* and *E. chapmani*. *C. umbonifera* indicates an age no older than late Early Miocene. In conjunction with observations from areas on Dudley Peninsula, a significant former extent of Miocene sediments in southwestern Kangaroo Island is indicated by the distribution of these rock clasts and of individual bioclasts of Miocene fossils in the aeolian deposits and calcretes we have examined at Kirkpatrick Point and Cape du Couedic.

4. Subsurface deposits

No Miocene sediments have been detected in any borings.

5. Remarks

With one exception, Miocene faunas have been identified from thin sections either of primary, mostly recrystallised limestones and calcarenites, or of clasts in younger aeolian complexes or calcretes, in a similar manner to that described from the Nullarbor Plain by Ludbrook (1970). Foraminifera are dominated by elphidiids, rotallids (mostly *Pararotalia*), and miliolids. They include *Pararotalia* sp., *Elphidium* "macellum", *E. chapmani*, *E. crassatum*, *Cibicides refulgens*, *Crespinella umbonifera*, and *Discorbis* spp. Algal fragments are common to abundant, and echinoid spines and bryozoan fragments are present.

The outcrops of fossiliferous sediments at "Willandra" and "Graydon" within the plateau province of the Island are regarded as remnants of more extensive deposition during major marine transgression in the Late Oligocene and Early Miocene, when mid-Tertiary seas entered nearby Myponga Valley and Hindmarsh Tiers (Ludbrook 1969; Lindsay *In Daily et al.* 1976).

All other materials assigned to the Miocene on faunal evidence on Kangaroo Island are of calcarenite aspect, consisting of well-sorted silt- to sand-size sediments containing both biogenic remains and quartz clasts. They crop out at lower levels in the landscape than the limestones at "Willandra" and until additional data are provided by further investigations they are hesitatingly regarded as a widespread blanket of near-shore or beach sediments deposited during regression of the Miocene seas.

Following regression of the seas during the Middle Miocene, there was an apparent hiatus in sedimentation throughout the St Vincent and Murray Basins, and this is generally regarded as the time during which weathering of the then exposed earlier Tertiary marine carbonate deposits produced extensive karst terrains (Ludbrook 1980). Reworking of the Miocene limestones on Kangaroo Island and the initial development of protective calcrete crusts by impregnation of outcrop remnants with secondary carbonate probably commenced at this time.

Pliocene

Marine sediments of Pliocene age are dominantly fossiliferous limestones widely distributed at low levels in the landscape compared with Miocene sediments. While Late Pliocene limestones and their faunas have been known on Kangaroo Island for some years (Ludbrook 1959), Early Pliocene sediments are here recorded for the first time.

(i) Early Pliocene

1. Point Reynolds

At "Table Rock", near Point Reynolds (section H hundred of Haines), the Kingscote Limestone is disconformably overlain by a white, conglomeratic sandy limestone containing abundant foraminifera, molluscs, and echinoid fragments including spines. Clasts of quartz and metasandstone up to cobble size are evident. The sandy limestone has a conspicuous rubbly weathering expression (Fig. 18) which facilitates its identification. It forms the basal bed of a sequence of thinly bedded, white sandy limestones and calcareous sandstones (Fig. 10) which appear to merge upwards into calcarenite dunes with distinctive large-scale cross-bedding. These sediments, covered by a complex calcrete crust, form the cliff tops. The lower part of this interval, beginning with the conglomerate, is dated Early Pliocene by foraminifera (J.M.L.) and molluscs (N.H.L.).

Foraminifera (all benthonic) include *Elphidium rotatum* (Early Pliocene), *Crespinella umbonifera* (late Early Miocene-Early Pliocene), *Fabularia howchini*, *Pararotalia hamiltonensis*, *Cibicides cygnorum*, and *Polymorphina myrae*, which together indicate a Kalimnan (Grange Burn, Jemmy's Point) Early Pliocene age. Other species present include *Elphidium crassatum*, *Epistomaroides polystomelloides*, *Ammonia beccarii*, and occasional reworked Eocene *Linderina glaessneri* and *Crespinina kingscotensis*. This microfauna has elements such as *C. umbonifera* and *F. howchini* in common with Early Pliocene sands recognised subsurface west of Naracoorte in southeastern South Australia (Lindsay In Cook *et al.* 1977).

The molluscs, which include *Chlamys anti-australis*, *Tellina (Pseudarcopagia) basedowi*, *Myadora corrugata*, and what may be *Hartungia dennanti dennanti*, are poorly preserved but

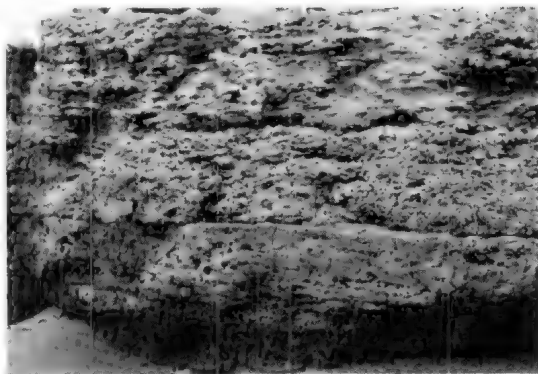


Fig. 18. Near centre of embayment at "Table Rock", Early Pliocene conglomeratic limestone with typical rubbly weathering character disconformably overlies Late Eocene echinoid limestone. Hammer (28 cm long) rests on contact.



Fig. 19. Thin section of packstone P188/71 (Majors & Vitols 1973) from Ravine des Cascares showing quartz, feldspar and biogenic clasts coated by dark micritic carbonate to form rounded sand- and silt-sized pellets. Fabric typical of reworked deposits. Bar scale 1 mm.

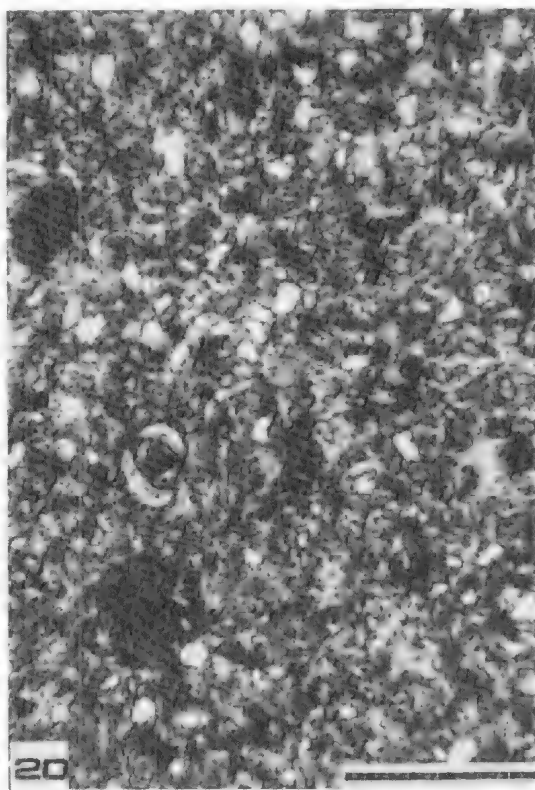


Fig. 20. Thin section of "York Farm" Late Pliocene white limestone M440, showing foraminifera and other biogenic remains, with some fine quartz clasts (white) and dark pelletal structures of possible algal origin, in fine carbonate matrix. Bar scale 1 mm.

also permit correlation with the Kalimnan of Grange Burn or Jemmy's Point in Victoria. Collections of echinoids from the unit are at present limited to fragments of what are doubtfully identified as *Arachnoides incisa* and *Peronella platynodes*. The Early Pliocene beds here are overlain, apparently conformably, by white bioclastic packstones and calcareous sandstones of Late Pliocene age correlated with the Hallett Cove Sandstone, and by the Early Pleistocene Point Ellen Formation. Younger calcarenites with distinctive large-scale cross-bedding are probably equivalent to the beach or back-shore dune deposits of the Pleistocene Bridgewater Formation.

2. Ravine des Casoars

Consolidated white and pink-red packstones that crop out adjacent to Ravine des Casoars south of Cape Borda, and similar material intersected in a water bore at Rocky River (section 1 hundred of McDonald), contain foraminifera which suggest an Early Pliocene age. Thin sections from Ravine des Casoars contain algal fragments, echinoid spines, and the foraminifera *Elphidium chapmani*, *Pararotalia hamiltonensis*, and unidentifiable species of *Elphidium*, *Pararotalia*, and a rotaliid. The rocks are composed of quartz clasts and bioclasts that are rounded and have a coating of micritic carbonate, and are comparatively well-sorted (Fig. 19). Those of pink to red colour commonly contain black limestone clasts and resemble palaeosols that occur within coastal aeolian calcarenite complexes. The textures of the rocks are consistent with reworking and transport of primary clasts, possibly in a beach or back-shore dune environment, and it is possible that the Early Pliocene foraminifera were inherited from a pre-existing sediment. Alternatively, the packstones may be Early Pliocene littoral deposits.

3. Pink Bay

North of Cape Willoughby, bioclastic grainstone is exposed in a cliff section about 50 m above sea-level at the back of Pink Bay. Biogenic material includes echinoid and mollusc fragments, foraminifera, and abundant dark coloured algal fragments; quartz clasts are rare to abundant. Round carbonate structures that are possibly recrystallised nodules also occur. This sandy limestone disaggregates to yield benthonic foraminifera which, although recrystallised, include common *Elphidium rotatum* and *Pararotalia hamiltonensis*, together

with less frequent *Notorotalia clathrata*, *Ammonia beccarti*, and *Elphidium crassatum*, and the occasional fragment of *Marghinopora vertebralis*. The assemblage is most likely of Early Pliocene age.

At both Cape Willoughby and Cape St Albans, there are thick calcretes capping prominent benches on the headlands about 50 m above sea-level. The calcretes are complex rocks of secondary origin, and they contain clasts and irregular relict zones of bioclastic packstone. Some of the clasts are dark-coloured due to a high content of carbonaceous material. In many samples of calcrete, there are zones in which quartz grains and bioclasts are coated with carbonate to form round pelletal structures which are cemented in a fine-grained secondary carbonate matrix. The pelletal structures typify physical reworking of the primary sediment, probably in a subaerial pedogenic environment. Impregnation of the reworked sediments by secondary carbonate can form very dense and tough calcretes which resemble fine-grained crystalline limestones.

Three random thin sections of the fossiliferous clasts from Cape St Albans, and one from Cannon Hill, Cape Willoughby, above the Point Ellen Formation, all contain similar fragmentary microfossils which include algal fragments, a species of *Elphidium* close to *E. macellum*, *Pararotalia* sp., miliolids, rotaliids, and bryozoan fragments. The assemblage may be compared with that in the fossiliferous limestones at Porky Flat and from the Nullarbor Plain, and a Miocene age presumed. No direct comparison with any material of Eocene or Pliocene age could be made, although correlation with Early Pliocene clasts from Pink Bay is not excluded.

In the outcrop at Pink Bay, there is considerable evidence of alteration by secondary carbonate. Moreover, the top of the section appears to be contiguous with the calcrete capping of the main headland. Thus, it is possible that the present surface distribution of calcrete reflects the former extent of the Miocene-Pliocene sediments, or may even be related in part to the distribution of the Early Pleistocene Point Ellen Formation, a remnant of which occurs south of Cannon Hill. Even the prominent ridge about 100 m above sea-level extending from Cape St Albans towards Cape Hart contains a veneer of calcrete over weathered bedrock in places. In the property

opposite the Cape St Albans turnoff from the Cape Willoughby road (section 386 hundred of Dudley), calcrete boulders containing ferruginous pisolites are heaped along the fences and were presumably gathered from adjacent paddocks. Here, the formation of calcrete post-dated the erosional reworking of the deeply weathered lateritic landscape, but the carbonate is still likely to have had an ultimate source in marine sediments which occupied the highest levels of the landscape.

4. Subsurface occurrences

a. Hundred of Haines

Pliocene sediments have been recognised in bores in the lowland area between Dudley Peninsula and the remainder of Kangaroo Island. The lower part of the section, at least, is of Early Pliocene age. Three bores from which only cable-tool sludge samples were available for examination were located on sections 22, 47 and 262 hundred of Haines.

The Pliocene sediments are typically weakly cemented, grey- or white-coloured, fossiliferous sandy limestones and calcareous sandstones. They reach a maximum thickness of at least 26.8 m between 16.8–43.6 m in C.S.R. bore 19 (section 22 hundred of Haines). *Crespinella umbonifera*, suggesting Early Pliocene age at the top of its range, is present rarely as high in the bore as 16.8 m. *Pararotalia hamiltonensis* occurs commonly as high as 18.3 m. The association of *P. hamiltonensis*, *C. umbonifera*, and *Elphidium rotatum*, at 18.3–19.8 m, is considered Early Pliocene. Although the top of the Eocene section is put tentatively at a sandy limestone/sand lithological boundary at a depth of 43.6 m, much Eocene bioclastic material is present in samples above this depth, presumably reworked. Recycled Eocene *Quasibolivina taylori* occurs as high as 18.3–19.8 m, while at a depth of 36.8–38.1 m, common *Q. taylori*, frequent *Linderina glauconeri*, and occasional *Halkyardia bartrami* and *Crespinina kingscotensis* are present.

b. Rocky River (section 1 hundred of McDonald)

Between at least 5.5 m and 7.0 m depth, Rocky River Department of Lands bore T.H.2 intersected oolitic limestone, sometimes with a very fine groundmass. The material is similar to that from Ravine des Cascoars, and contains a similar Early Pliocene foraminiferal association of *Pararotalia hamiltonensis*, *Cres-*

pinella umbonifera, and *Elphidium rotatum*. The packstones are overlain by Late Pleistocene sediments.

5. Remarks

Although Early Pliocene sediments are here recorded from Kangaroo Island for the first time, they are still very imperfectly known. Outcrops are poor and difficult of access. Further collecting and study of the echinoids and other faunal elements at the base of the Pliocene outcrop at "Table Rock" is required.

The beds appear to correlate with an unnamed, probably Early Pliocene subsurface unit of limited distribution in the Adelaide Plains Sub-Basin ("Croydon facies" of Lindsay 1969), and with the Bookpurnong Beds or basal Loxton Sands of the Murray Basin.

(ii) Late Pliocene

Remnants of deposits from Late Pliocene seas occur more widely in the lowland areas. These are equivalent to the Hallett Cove Sandstone of the Adelaide region and, together with the Dry Creek Sands, are regarded as deposits from a widespread transgression.

At "Table Rock" near Point Reynolds, Late Pliocene packstones and calcareous sandstones containing *Marginopora* overlie the Early Pliocene sediments with apparent conformity. Elsewhere there are isolated outcrops of Late Pliocene shelly limestones widely scattered across Kangaroo Island about 30 m above sea-level.

1. Gum Creek (sections 265, 266, 268, 269, 273, 281, 308 hundred of Menzies)

Within the Nepean lowland, dense red to grey cemented limestones crop out rather poorly on low bush-covered rises about 30 m above sea-level adjacent to Gum Creek. They were regarded by Glaessner & Wade (1958) as Oligocene–Miocene, although Bauer (1959) preferred a Pliocene age. Ludbrook (1959, 1963) subsequently identified the molluscan fauna including *Chlamys* species in association with *Ostrea* as Pliocene, and correlated the limestones with the Hallett Cove Sandstone of the Adelaide region. There are no field relationships exposed, although in section 308 hundred of Menzies bedrock metasandstones crop out on the flanks of the rise, suggesting that the limestone was deposited directly onto bedrock. In this locality, white fossiliferous limestone similar to the white crystalline limestone at "York Farm" is well exposed. Mollusca in the form mainly of casts and moulds

are abundant, and include *Glycymeris* sp., *Chlamys* (*Chlamys*) *antiaustralis*, *Chlamys* (*Equichlamys*) *palmipes*, *Gibbolucina* (*Gibbolucina*) *sulcatosa*, *Neritina* *lata*, *Aerostrepta* *poeygivera* and *Dentalium* *lanceolatum*.

The limestones are coarse-grained and poorly-sorted packstones with abundant biogenic debris including bivalve fragments, foraminifera, probable bryozoans, corals and gastropods, and subangular to subrounded quartz clasts. Some samples contain mud lenses with silt-size clasts of biogenic material and quartz. The red limestones are characterised by matrix carbonate stained with iron oxide.

There is an abundant molluscan fauna, mainly in the form of moulds and casts, dominated by *Chlamys* (*Chlamys*) *antiaustralis*, together with *Chlamys* (*Equichlamys*) *consobrina*, *Spemylus* *spemylus*, *Ostrea* sp., *Cardita subdeceptiva*, *Zenatta* (*Zenatopsis*) sp., *Barbatia* sp., *Gazameda adelaidensis* and *Dicathema adelaidensis*.

2. "Kent Lagoon" (section 172 hundred of Haines)

South of the Cygnet Scarp, grey to brown fossiliferous sandstones and dense micritic limestones crop out, albeit poorly, beneath a calcrete capping in a shallow cliff section 6–7 m high on the southern margin of an intermittent lagoon ("Kent Lagoon"). The outcrop is between 20–30 m above sea-level. Bauer regarded the sediments as Pliocene on the basis of faunal identifications by Cotton. *Chlamys antiaustralis* is the conspicuous bivalve in the calcareous sandstones near the base of the section and from its preservation and abundance, immediately invites comparison with the sediments at Gum Creek.

Units near the top of the section include a dense, brown micritic limestone containing quartz clasts up to pebble size, and some fossils including gastropods. It is complexly laminated in thin section, with spherules and vugs filled with crystalline calcite. The micritic carbonate appears to be of secondary origin, and may be related to the development of the overlying calcrete crust. As at Gum Creek, the field relationships of the limestones are not exposed. A sample of pebbly quartzose sandy limestone was disaggregated with difficulty to yield a few heavily recrystallised foraminifera including *Ammonia beccarii*, *Elphidium rotatum*, *E. cf. crispum*, and fragmentary *Marginopora vertebialis*. This assemblage is consistent with

a Late Pliocene age. Foraminifera in the one random section examined are poor and limited to species of *Elphidium*, *Ammonia beccarii* and rotaliids; sections through bivalve shells and an echinoid spine are also present.

The sediments in this locality contain conspicuous black carbonaceous matter, and emit a distinct petroliferous odour when freshly broken. In places, brecciated zones containing carbonaceous matter in patches, veins and as borders around clasts, occur within the sediments. In thin section, the organic material is generally interstitial and occurs in stringers, wisps and pockets aligned parallel to bedding laminations. Additionally, clear calcite-lined vugs are in some cases filled with the organic matter. Through the courtesy of D. M. McKirdy, the organic matter was extracted from some samples and identified by capillary gas chromatography to be predominantly of algal origin with a minor higher plant component. The presence of such organic matter in the "Kent Lagoon" sediments points to a restricted marine environment.

3. "York Farm" (section 134 hundred of Haines)

Samples of white, finely crystalline limestone present in the GSSA Palaeontology Collection were collected by R. F. Harris on the property "York Farm" south of Western Cove on the Kingscote–Penneshaw road. Outcrops of the limestone (Fig. 20) containing internal moulds of bivalves and gastropods were located near the summit of a low hill southwest of the farm buildings. Many boulders of calcrete are scattered over the hillslope and adjacent areas, probably indicating a wider subsurface extent of the limestone. Scattered boulders of bedrock Kanimambur Group metasediments are common and reflect the local development of Permian glaciogenic sediments, as well as the probable existence of bedrock at shallow depth beneath the limestone.

Partway down the northeastern slope of the hill, boulders of ferruginised sand packed with internal and external moulds of molluscs are found. The ferruginised sandstone contains an abundant, although poorly preserved Late Pliocene molluscan fauna of which fourteen species have been identified. They include *Chlamys* (*Chlamys*) *antiaustralis*, *Glycymeris* (*Veletucella*) *pseudaustralis*, *Anodonta spheri-cula*, *Cucullaea puerlinga*, *Myadora corrugata*, *Eurassatella kingicoides*, *Campanile miserale* and *Dentalium lancesulatum*.

The field relationships between the fossiliferous limestone and the ferruginised sandstone are not exposed, but their distribution and association with an abundance of calcrete is encouragement for further mapping.

4. Cape Borda

Fossiliferous sandy limestone which crops out 0.5 km ESE of Cape Borda Lighthouse, appears, from a single random thin section, to be comparable with a similar section from white miliolid limestone at "York Farm". The rock is a pink-cream, fine-grained micro-breccia with angular fragments set in a very fine groundmass. Foraminifera are difficult to identify with certainty but include miliolids, rotaliids, *Elphidium* sp. cf. *E. "macellum"*, *Elphidium* sp. cf. *E. adelaidense*, *Cibicides refulgens*, *Pararotalia* sp. and *Textularia* sp. Algal fragments, echinoid spines and spicules are also present. The limestone was described by Major & Vitols (1973) Amdel Report P187/71. From its resemblance to the limestone at "York Farm", that at Cape Borda is tentatively regarded as of Late Pliocene age.

5. Remarks

Although poorly preserved as casts and moulds, the molluscs that occur in abundance at Gum Creek and "York Farm" in limestones and ferruginised sandstone are similar to those occurring in the Dry Creek Sands and the Hallett Cove Sandstone. Important species are *Cucullaea praelonga*, *Eucrassatella kingi-coloides*, *Acrosterigma praecygnorum*, *Campanile triseriale* and *Gazameda adelaidensis*. Foraminifera in disaggregated samples and thin sections of the limestones lack *Crespinella umbonifera* or restricted Kalimnan species, and mainly comprise rotaliids, elphidiids, and miliolids which range through to the present day. *Elphidium* sp. cf. *E. adelaidense* may be common.

Quaternary

Pleistocene

Pleistocene marine sediments occur at low levels in the landscape. Early Pleistocene sediments are known from outcrop remnants at only four localities on the modern coastline, where they have survived erosion partly through the protective influence of bedrock outcrop, but also through the development of calcrete carapaces. Late Pleistocene sediments are occasionally cemented by secondary carbonate in areas where there has been evaporation of carbonate-charged percolating waters.

In the main, they are confined to lowland areas adjacent to the modern coastline where they may occupy the floors of contemporary carbonate and saline ephemeral lakes.



Fig. 21. View of cliff section through Early Pleistocene Point Ellen Formation (approx. 2.5 m thick) unconformably overlying steeply-dipping Kanmantoo Group bedrock at Point Ellen. Bottom part of Point Ellen Formation comprises coquinite with abundant large and thick-shelled molluscs. Overlying beds contain many angular bedrock clasts in matrix of coquinite. Uppermost part of section is calcreted. Hammer (encircled) 28 cm long.

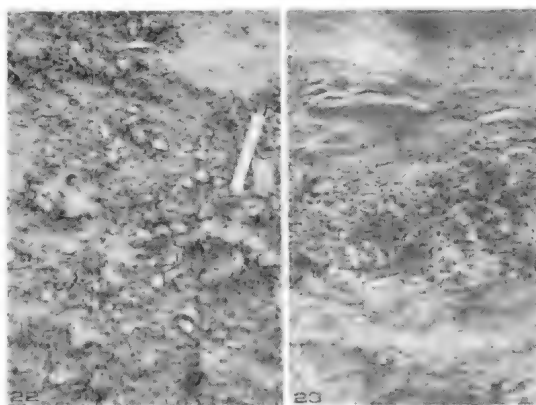


Fig. 22. Facies of Point Ellen Formation coquina rich in *Nerita* sp. nov. near western limit of outcrop. Pen 14 cm long.

Fig. 23. Basalt conglomerate overlying Kingscote Limestone in Kingscote cliffs. Note discoidal shape of clasts (some of which are quartz and limestone) and fine carbonate matrix. Upper part of profile heavily impregnated and cemented by secondary carbonate, though basalt clasts can still be discerned. Thin calcareous soil on top. Hammer 28 cm long.

(i) Early Pleistocene

An Early Pleistocene fauna is recognised on Kangaroo Island for the first time. It occurs at three localities, Point Ellen, "Table Rock", and Cape Willoughby, and also as a remnant at Cape Jervis on Fleurieu Peninsula on the adjacent mainland.

1. Point Ellen

Point Ellen Formation New stratigraphic unit.

Type section: The type section is exposed in the sea-cliffs at Point Ellen at the south-western entrance to Vivonne Bay, in the Marine Board Reserve adjacent to section 106 hundred of Newland.

Lithology: Richly fossiliferous limestone and coquina composed predominantly of fossil gastropods.

Thickness: Variable, but up to 2 m.

Distribution: Limited to a small area at Point Ellen, overlying Late Pliocene sediments in the "Table Rock" cliff section, a small outcrop at Cape Willoughby and a thin remnant overlying the Cape Jervis Beds at Cape Jervis.

Age: Early Pleistocene.

On the ocean coastline of Point Ellen, just south of the car park, the bedrock Kanmantoo Group metasediments are overlain with marked unconformity by richly fossiliferous coquina (Fig. 21). These sediments infill a highly irregular surface eroded in the bedrock, and clearly represent deposition in a restricted bay or inlet on a rocky coast. Abundant cobbles and boulders of bedrock metasediments occur within the fossiliferous sediments. In some places, there are beds crowded with gastropods including a new species of *Nerita* (Fig. 22). The section is of highly variable thickness to a maximum of 2 m because of the irregular topography of the bedrock unconformity, and is capped by a complex calcareous profile. Towards the eastern end of the outcrop, conspicuous large solution pipes extend through the calcareous capping and the fossiliferous sandstones, and bottom on bedrock at the unconformity.

The rich molluscan fauna can be directly correlated with that of the Roe Calcareous in the Eucla Basin described by Ludbrook (1978). Its most important constituent is the pelagic janthinid gastropod *Hartungia demmanni chavani* which is conspicuous among the mass of *Nerita* shells in the cliff face. This molluscan fauna, so far unrecognised in South Australia, is reported in a separate paper

(Ludbrook 1983) which includes a description of the new species of *Nerita* and a new lucinid.

Specimens first collected from this locality in 1914 by Arthur Wade were identified by F. Chapman. Most of Wade's material is in the Palaeontological Collection of the Geological Survey of South Australia, but some was retained in the National Museum of Victoria, including the holotype of *Glycymeris australis* var. *gigantea* Chapman, which is a specimen of *Anodontia sphericula* (Basedow), common in both the Hallett Cove Sandstone and the Roe Calcareous, and having a range of Middle Miocene to Early Pleistocene.

Chapman correctly determined the fossils from Point Ellen as "equivalent to the Werrikoonian of Victoria or Upper Pliocene". The Werrikoonian Limestone in Victoria is now considered to straddle the Pliocene-Pleistocene boundary, the foraminifera indicating that only the lower part including the basal shell bed is of probable Late Pliocene age, the rest being Early Pleistocene (Singleton *et al.* 1976). Problems of making direct faunal correlation between the Point Ellen Formation and the Werrikoonian Limestone are twofold: first, no modern descriptions or differentiated lists of Werrikoonian molluscs from the Glenelg River sequence are published and, secondly, depositional environments were sufficiently different to be reflected in the assemblages.

The western side of the Point Ellen outcrop was illustrated by Daily *et al.* (1979), who considered the presence of *Anodontia* to indicate a possible Pliocene age. This is not supported by the stratigraphical range of *Anodontia sphericula*. Other Roe Calcareous species occurring in the Point Ellen Formation include *Tinoclea* (*Veremolpa*) *kendricki*, *Monilea euclensis* and *Hartungia demmanni chavani*. Foraminifera are poorly represented, but include *Ammonia beccardi*, *Elphidium rotatum* and *Epistominoides polystomellaeides*, all of which are species still living.

2. "Table Rock"

Calcareous sandstones containing abundant moulds and casts of molluscs, including *Monilea euclensis* and *Nerita* sp. nov. of the Point Ellen Formation, are interbedded with thin calcarenites above Late Pliocene beds in the cliff section at "Table Rock". The beds are identified as the flaggy unit in Figure 10 immediately below cross-bedded calcarenites identified with the Bridgewater Formation.

3. Cape Willoughby

A careful search at Cape Willoughby identified the outcrop described by Howchin (1903) as "sparingly fossiliferous" to consist of, in fact, calcareous sandstones containing abundant fossils including molluscs, bryozoans and cirripedes. The outcrop occurs on the southwestern side of Cannon Hill where the sandstones overlie a highly irregular surface of weathered granite and contain much granitic debris, including large boulders that appear to have rolled down from the adjacent ridge during sedimentation. There is a section about 3-4 m high and about 10 m above sea level comprising well-bedded fossiliferous sands at the base, with coarse bioclastic grainstones of possible back-beach origin interbedded with finely laminated green-brown micritic limestones above. Large solution pipes partly infilled with red mottled soil material occur in the section, which is capped by the calcareous crust that forms a conspicuous carapace over much of the headland.

The fossiliferous sandstones at Cape Willoughby contain the *Nerita* sp. nov. of the Point Ellen Formation, *Tinivlea* (*Veremolpa*) *kendricki*, and *Diastoma melanioides*. The microfauna includes abundant *Marghinopora vertebralis*, together with *Flintina triquetra*, *Ammonia beccarii*, *Elphidium rotatum*, *Cribroballina polystoma* and *Peneroplis* sp. Conditions of deposition must have been similar to those on the continental shelf along southern Australia at the present day, as described by Conolly & von der Borch (1967) and Wass *et al.* (1970). Like the modern sediments, the fossiliferous sandstones at Cape Willoughby doubtless include a good deal of reworked material.

4. Cape Jervis (section 318 hundred of Yankalilla)

A thin exposure of Point Ellen Formation 570 m northeast of Cape Jervis Lighthouse on Fleurieu Peninsula is included here because of its proximity to Kangaroo Island and because the faunal content is very similar to that of the type section at Point Ellen.

The outcrop was first recorded by Howchin (1918) as one of the raised sea beaches seen in the sea cliffs in many places along the southern coast of Australia. These are mostly equivalent to the Glanville Formation. The remnant was not observed by Wilson & Ludbrook (In Ludbrook 1967), who recorded the

Permian Cape Jervis Beds as overlain by kunkar.

In 1982, a field party from the Geological Survey of South Australia collected molluscs from a thin limestone remnant at the base of the calcarete overlying the Cape Jervis Beds at their type section on section 318 hundred of Yankalilla. These included the new species of *Nerita* in abundance, together with *Hartungia dennanti chavani* and about seventeen other species. Like the fauna at Point Ellen, the assemblage indicates an open sea, high energy coast environment. The presence of a cobble bed containing mainly rounded clasts of Kanmantoo Group metasediments at the base of the limestone reflects such an environment.

5. Remarks

Despite the difficulties expressed above in making direct faunal correlations, the Point Ellen Formation is stratigraphically equivalent to the Roe Calcarene of the Eucla Basin. It is probably equivalent also to the Coomandook Formation of the Lower South-East of South Australia, the Burnham Limestone of the St Vincent Basin, and the Werrikoo Limestone of western Victoria, but these formations and their faunas are inadequately known. The molluscs of the Point Ellen Formation and Burnham Limestone are described by Ludbrook (1983).

(ii) Late Pleistocene

Rejuvenation of faulting after deposition of the Early Pleistocene Point Ellen Formation heralded a return to terrestrial environments until a major marine transgression in the Late Pleistocene and the widespread deposition of sediments assigned to the Glanville Formation. Correlations of shell beds of this age are usually possible on the basis of palaeontological data, but further field work and the application of amino-acid racemisation studies presently in progress in the CSIRO Division of Soils laboratories may assist in verifying that only one transgression occurred on Kangaroo Island in the Late Pleistocene.

Sediments containing rich molluscan faunas exactly similar to those of the widespread Glanville Formation were collected from several localities on Kangaroo Island, mostly from shallow quarries and roadside scrapes. They include the basalt conglomerate overlying the Kingscote Limestone at Kingscote, shallow roadside quarries near Vivonne Bay, Rocky Point and nearby shallow quarries adjacent

in the Penneshaw road, the gypsum workings in New Lake, and the Rocky River water bore mentioned previously.

1. Kingscote

A basalt conglomerate unconformably overlies the karst surface on the Kingscote Limestone in many places (Fig. 23). It is a typical beach shingle deposit, comprising rounded discoidal pebbles and cobbles of Wisanger Basalt, and less commonly other rock types including limestones and quartz, lying roughly parallel to the base of the deposit and set in a very fine-grained carbonate matrix containing some sand-sized quartz clasts and an abundant molluscan fauna. The conglomerate is usually at the base of a calcrete profile which is well exposed in the coastal cliffs. In many places beneath the conglomerate there are pockets and fissures in the limestone filled with brown clay.

Howchin (1899) regarded the conglomerate as a stranded Recent coastline deposit; Bauer (1959) suggested a Pleistocene age based on identification of the molluscs by Cotton.

The conglomerate contains *Marginopora vertebralis* and twenty species of Mollusca including *Euplicia bidentata*. The fauna is a thanatocoenose, most of the specimens having been transported from more than one environment and considerably worn, but with the few exceptions of those which lived on rocks, they were inhabitants of sand or sandy mud in the littoral zone. The most common species are *Katelysia peronii*, *K. rhytiphora*, *Antesodesma angusta*, *A. cuneata*, and *Cominella lineolata*.

The assemblage is considered to be of Late Pleistocene age and the conglomerate equivalent to the Glanville Formation.

2. Vivonne Bay road

This roadside quarry is the locality of Wade (1915) at the "mouth of the Eleanor River, Vivonne Bay", from which Chapman identified five species of molluscs. The same fauna was recollected. The assemblage is a bioecoenose, almost all of the six species collected in abundance being intertidal inhabitants of estuaries, sandflats or mudflats. The most abundant are *Anapella cycladea*, *Tellina* (*Macanoma*) *detritidula* and *Niotha pauperata*; *Anadara trapezia* is present.

3. Rocky Point and shallow quarries adjacent to Penneshaw road (section 289 hundred of Dudley)

Like the basalt conglomerate at Kingscote, the powdery limestone plastered against the

cliffs at Rocky Point contains some species such as *Nerita* (*Melanerita*) *atraementosa* which prefer a rocky environment, but most of the twenty-three species identified are inhabitants of sand or sandy mud in the littoral zone. The faunas in the carbonates of the shallow quarries on either side of the road near Rocky Point are mostly bioecoenoses dominated by *Marginopora vertebralis*, *Antesodesma angusta*, and *Diala lauta*.

4. New Lake (south of section 288 hundred of Dudley)

Carbonate sediment with abundant molluscs below gypsum in New Lake is also possibly to be correlated with the Glanville Formation, although none of the diagnostic forms was recovered. The molluscan fauna is a bioecoenose of fifteen species, dominated by *Fulvia tenuicostata* which lives gregariously in sand and mud at water depths from 2–30 m; *Diala lauta* and *Bitium* (*Semibitium*) *granatum* are common.

5. Section 11 hundred of Haines

Material recovered from a shallow well on the property of D. A. Lovering contains abundant molluscs including *Katelysia rhytiphora*, *K. scalarina*, *Sanguinolaria* (*Psammotellina*) *hiradiata*, *Venerupis galacites*, *Brachidontes erosus* and *Batillaria* (*Zeacumantus*) *diemenensis*. As none of the usual diagnostic forms appear to be present, like New Lake, it can only doubtfully be referred to the Glanville Formation.

Holocene

Holocene equivalents of the St Kilda Formation have been found on the eastern margin of the Island adjacent to the Bay of Shoals and Antechamber Bay.

1. Bay of Shoals (section 5 hundred of Menzies)

Stranded beach deposits comprising flattened beach shingle arranged in imbricate pattern with abundant mollusc remains overlie Permian glaciogenic sediments along The Bluff road N. of Kingscote. From samples taken at the base and top of the deposit, twenty-three species of Mollusca dominated by gastropods were identified. The assemblage is very similar to that of the St Kilda Formation at St Kilda. *Batillaria* (*Zeacumantus*) *diemenensis* is the most abundant species; *Niotha pyrrhus*, *N. pauperata* and *Bedeva paivae* are common. *Katelysia peronii*, *K. rhytiphora*, *K. scalarina*,

and *Amesodesma cuneata* are the most ubiquitous bivalves. Neither *Anadara trapezia*, *Euplicia bidentata*, nor *Marginopora vertebralis* is present.

2. *Antechamber Bay road* (section 58 hundred of Dudley)

The shell sand obtained from auger holes at 0.3 m and immediately below the surface contains abundant *Niotha pauperata*, *Tellina* (*Macomona*) *deltoidalis* and *Munditia hedleyi* with *Batillaria* (*Zeacumantus*) *diemenensis* and *Eumarcia fumigata*. It is considered equivalent to the St Kilda Formation.

3. *Remarks*

Examination of contemporary beaches on the coasts indicates that the Holocene sediments were deposited under similar conditions to those existing at the present time. There is a restricted fauna, with individuals of littoral and marginal lagoon species of *Amesodesma*, *Katelysia*, and *Niotha*, as well as *Batillaria* (*Zeacumantus*) *diemenensis* and *Eubittium lawleyanum*.

Quaternary deposits of uncertain age

1. *Point Tinline* (section A hundred of Haines)

The carbonate sediment near Point Tinline contains abundant *Coxiella striata* with *Batillaria* (*Zeacumantus*) *diemenensis*, *Phasianella angasi* and *Bedelevia paiva*. This is a marginal lagoon deposit, difficult to correlate with either the Glenville or the St Kilda Formation. It can only be described as Quaternary.

2. *E. & W.S. Pumphouse bore* (section 2001 hundred of Menzies)

Between 7.6–11.3 m and between 15.2–15.8 m in this bore, 2.7 km from the mouth of the Cygnet River, fragments of *Diala lauta* and other gastropods, and of *Katelysia scalarina*, indicate deposition in a tidal inlet.

3. *Remarks*

Bauer used the distribution of all these sediments, together with geomorphic observations of contiguous erosional surfaces or benches, to deduce a 3–5 m sea-level of "Pleistocene to mid-Recent" age.

Relationships between Cainozoic marine sediments and present landscape

As part of his extensive field investigations, Bauer (1959) prepared a broad-scale topographic map of Kangaroo Island and sought to explain the origins of the landscape. In

doing so, he postulated six surfaces of marine origin from Late Pleistocene to Recent age, ranging in elevation from 122 m to 3 m above sea-level. His evidence was discussed by Daily *et al.* (1979), who concluded that definite marine terraces occurred only at 3–5 m and 6–8 m above present sea-level, and were of Pleistocene age; platforms at higher elevations may, for example, be relict fragments of ancient coastal plains.

Bauer's topographic map is in general agreement with a map outlining the soil landscapes of the Island (Northcote 1979), based on earlier soil survey data (Northcote & Tucker 1948; Northcote 1949, 1950), and the geological map of Sprigg (1954). The plateau province of Bauer, extended by Northcote into the Seddon and Gosse plateaux and the MacDonnell Hills landscapes, comprises mainly duplex soils with ferruginous gravels and acid duplex soils. The same soils occur in the eastern part of the Island on Dudley Peninsula, which Northcote described as "Hilly uplands with laterite remnants" and assigned to his Penneshaw hills and ridges landscape. Together these regions encompass the ancient upland deeply-weathered landscapes with conspicuous local development of ferruginous materials. The southern and western margins of the Island are dominated by the calcareous coastal province of Bauer, which corresponds to Northcote's Linois province. Soils in these areas are mainly shallow red-brown sandy soils. The main plains and lowlands occur north and south of the Cygnet Scarp, and exhibit predominantly alkaline duplex soils which reflect the influence of introduced calcium carbonate.

Eocene limestones occur at comparatively low levels in the landscape and subsurface in the Nepean lowland (encompassing Bauer's Nepean Embayment and the Cygnet plains and Menzies hills landscapes of Northcote), adjacent to Flour Cask Bay, and on the coast near Point Reynolds. In Freestone Creek, the Eocene outcrop is about 60 m above sea-level. Clearly, the Eocene sediments are remnants of a wider distribution on the Island, though the Eocene seas may not have extended far beyond the modern coasts. Clasts of basalt found in pebble beds in the Eocene limestones at Kingscote attest to erosion of the Wisanger Basalt exposed at that time in adjacent lands. The landscape inundated by the Eocene seas is to some extent still preserved beneath Eocene

limestones in parts of the coastal and lowlands provinces on the Island, and it is likely that further sediments will be found subsurface by drilling in these areas. There is no evidence for encroachment of the seas onto the present plateau provinces, and no apparent relationship between landscape elements in these provinces and a possible base-level of erosion dictated by the Eocene seas. In any case, there has been considerable disruption of the landscape by movement along the Cygnet and Snelling Faults in post-Eocene times. One effect of this movement has been to create the fault-angle depression represented by the Nepean lowland in which a sequence of Eocene limestones has been preserved above Late Palaeozoic glauconitic sediments. It has been generally considered that sedimentation occurred preferentially in this fault-controlled depression as in those of the eastern St Vincent Basin. However, this cannot yet be regarded as proven. The Kingscote Limestone does thicken southwestwards from Kingscote to a known maximum of about 50 m at the Pumphouse bore, but no thicker section has yet been confirmed; and unfortunately, the limestone has not been penetrated in any bores nearer the Cygnet Fault in what might be presumed to be the deeper part of the Tertiary basin. An incomplete 45 m-thick section of the limestone was intersected in this area in the Willis & Bishop No. 2 bore (section 1 hundred of Macgillivray), but deeper drilling is needed in the fault-angle depression to determine the thickness and succession of the limestone there.

By way of contrast with the distribution of Late Eocene limestones, marine sediments of probable Miocene age from "Willandra" and Mounts Taylor and Stockdale respectively occur within the plateau province at elevations in excess of 100 m above sea-level. Rocks of similar age at Kelly Hill Caves and in the Porky Flat area occur in the Linois province of "rough, broken calcarenite lowlands" (Northcote 1979), and are about 50 m above sea-level. Geologically, the Linois province is complex: in addition to a possible base of Eocene limestones and outcrops of Miocene limestones, reworked clasts of Miocene-Pliocene sediments are contained within calcrete veneers over benches and surfaces at Cape St Albans and Cape Willoughby, and in sequences of calcarenite dunes with interbedded palaeosols at Kirkpatrick Point and Cape du Couedic. In addition, the province contains conspicuous

calcarenites of Pleistocene age which, for example near Point Reynolds, overlie Early and Late Pliocene and Early Pleistocene sediments. It is clear that Miocene sediments were formerly widely deposited on Kangaroo Island (including parts of the plateau province) in response to one or more major transgressions, and that significant modification of the landscape would have been achieved by the encroaching Miocene seas with accompanying changes of base-level of erosion. Removal of all but remnants of the Miocene marine deposits from the interior of the Island makes difficult any judgement of the extent of the transgressions and their detailed geomorphic effect. Elsewhere in the St Vincent Basin, seas regressed in the Middle Miocene in response to widespread uplift of continental margins. On Kangaroo Island at this time, movement along the Cygnet and Snelling Faults further effected changes in the landscape and it is likely that the emergence of much of the Island's landscape during this regression initiated terrestrial reworking of the Miocene deposits and the extensive formation of secondary carbonates and calcretes. There are calcrete-covered benches 80–100 m above sea-level around the margins of the Wisanger Basalt forming the Gap Hills within the Nepean lowland. Based on position within the landscape, these benches and possibly the calcium carbonate in the calcretes covering them may be related to the distribution of the Miocene marine sediments, though no outcrops of such are known north of the Cygnet Scarp. Much calcium carbonate also impregnates the surface zones of the basalt in places.

Early Pliocene elastic limestones occur in sequence over the Eocene limestones in coastal outcrops about 10 m above sea-level near Point Reynolds. Bioclastic grainstones with Early Pliocene foraminifera from Ravine des Casnars and the Rocky River water bore are up to 50 m above sea-level within the Linois province, but appear to have been deposited during a phase of reworking of Early Pliocene sediments. In addition to the coastal sequence near Point Reynolds, remnants of Late Pliocene shelly limestones and calcareous sandstones occur in the present plains and lowlands up to 30 m above sea-level at "Kent Lagoon" and "York Farm" in Northcote's Macgillivray plains province, and at a similar elevation along Gum Creek near the edge of the Nepean lowland. The sediments all appear to have

been deposited in near-shore environments with significant contributions of terrestrial material.

The location of the shorelines cannot be deduced from the known distribution of the sediments, nor is it clear whether the entire area was inundated or whether deposition occurred only in embayments, estuaries or inlets. In a general sense, however, it is likely that the shores flanked the margins of the current plateau provinces. The plains and lowland landscapes with which the Pliocene sediments are associated comprise riverine or swamp and lagoonal lowlands, and are characterised by alkaline duplex soils (Fig. 24) which do not occur at higher levels in the landscape. The soils record the influence of calcium carbonate that may have derived from either the local reworking of Pliocene marine sediments, or from downwasting of Miocene marine sediments from the higher level plateau provinces.

Pleistocene marine sediments are confined to the lowland areas immediately adjacent to the present coastline, consistent with deposition in shallow waters during periods of high sea-level. Early Pleistocene sediments at Point Ellen, "Table Rock" and Cape Willoughby

were deposited on rocky coasts by seas still significantly above present levels, and are probably related to the 6–8 m sea-level stand postulated by Bauer (1959), for which there is extensive geological evidence. Based on studies in the Adelaide region, major uplift along the faults bounding the Mount Lofty Ranges occurred in the Middle Pleistocene and initiated deposition of thick wedges of alluvial outwash which covered the Tertiary and Early Pleistocene marine sediments. The remnants of such deposits form a narrow coastal plain (the Red Banks) flanking the Cygnet Scarp along the southern margin of Nepean Bay. The lower beds in this sequence are red alluvial clays and gravels which are extensively mottled and leached. The upper beds, in sharp contact with the lower beds, comprise white, carbonate-rich alluvial deposits (Fig. 25). Similar sequences of sediments are well known in the St Vincent and Murray Basins, though none have been studied in detail. The upper carbonate-rich interval appears to represent an abrupt change in the nature of the source material in landscapes that were eroding at this time. However, it is also possible that the junction between the upper and lower intervals records a significant time break, sufficient for carbonate originally present in the lower beds to have been leached before renewed activity along the Cygnet Fault led to deposition of the upper carbonate-rich sediments. Whatever the explanation, the sequence as a whole points to uplift of the southern part of the Island relative to the Nepean lowland during at least the Middle Pleistocene, and thus disruption and erosional modification of the earliest Pleistocene landscapes which incorporated the emergent Palaeogene and older Neogene marine deposits.

Late Pleistocene marine sediments of beach and estuarine origin occur at low levels near the coasts, corresponding to Bauer's 3–5 m sea-level. Lowland areas, for example west of the Bay of Shoals and in the regions of Eastern Cove, Pelican Lagoon and Flour Cask Bay, were inundated at this time.

Acknowledgments

Diagrams were prepared by CSIRO Division of Soils and SADME, and the photographic prints by John Coppi. R. P. Bourman kindly collected the sample from section 11 hundred of Haines. N.H.L., J.M.L. and B.J.C. publish with permission of the Director-General, S.A. Department of Mines & Energy.

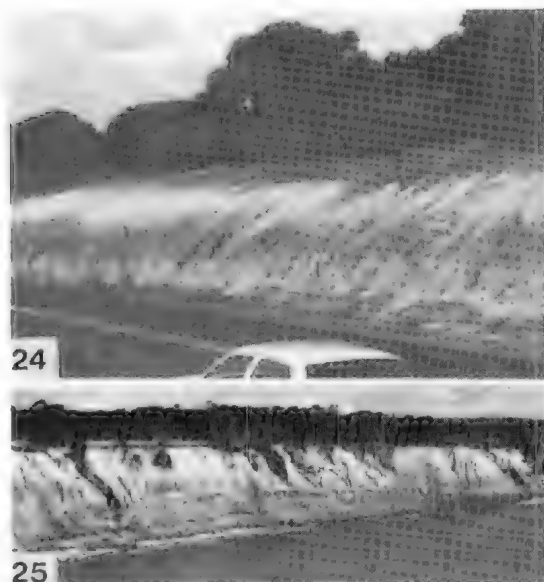


Fig. 24. Alkaline duplex soil with thick carbonate accumulation zone (white) developed on hill-tops in Penneshaw Hills landscape along Kingscote-Penneshaw road near "York Farm".

Fig. 25. View of deposits forming the Red Banks, comprising lower unit of mottled reddish clays and gravels, and overlying light-coloured carbonate-rich alluvial sediments. Height of cliffs approx. 8 m.

References

- BAUER, F. H. (1959) The regional geography of Kangaroo Island, South Australia. Ph.D. thesis, Aust. Natl Univ., Canberra (unpubl.).
- BLOW, W. H. (1979) The Cainozoic Globigerinida. 3 vols. (E. J. Brill: Leiden.)
- BREYS, C. (1962) Groundwater prospects—portions of the hundreds of Haines and Dudley Final report, *Min. Rev. Adelaide* 114, 13-18.
- BOURMAN, R. P. & LINDSAY, J. M. (1973) Implications of fossiliferous Eocene marine sediments underlying part of the Waitpinga Drainage Basin, Fleurieu Peninsula, S.A. *Search* 4, 77.
- CHAPMAN, F. (1915) Report on a collection of fossils made by Dr A. Wade from the Cainozoic series of South Australia. Appendix II, Wade, A. The supposed oil-bearing areas of South Australia. *Bull. geol. Surv. S. Aust.* 4, 44-50.
- CONOLLY, J. R. & VON DER BORCH, C. C. (1967) Sedimentation and physiography of the sea floor south of Australia. *Sediment. Geol.* 1, 181-220.
- COOK, P. I., COLWELL, J. B., FIRMAN, J. B., LINDSAY, J. M., SCHWEBEL, D. A. & VON DER BORCH, C. C. (1977) The late Cainozoic sequence of southeast South Australia and Pleistocene sea-level changes. *BAIR II Aust. Geol. Geophys.* 2, 81-88.
- COOPER, B. J. (1979) Eocene to Miocene stratigraphy of the Willunga Embayment. *S. Aust. Dept. Mines Rept. Invest.* 50.
- (1981) Carboniferous and Permian sediments in South Australia and their correlation. *Q. geol. Notes, geol. Surv. S. Aust.* 79, 2-6.
- & LINDSAY, J. M. (1978) Marine entrance to the Cainozoic St Vincent Basin. *Ibid.* 67, 4-6.
- DAILY, B., FIRMAN, J. B., FORBES, B. Q. & LINDSAY, J. M. (1976) Geology. In Twidale, C. R., Tyler, M. J. & Webb, B. P. (Eds) "Natural History of the Adelaide Region", Ch. 1, 5-42. (R. Soc. S. Aust.: Adelaide.)
- , MILNES, A. R., TWIDALE, C. R. & BOURNE, J. A. (1979) Geology and geomorphology. In Tyler, M. J., Twidale, C. R. & Ling, J. K. (Eds) "Natural History of Kangaroo Island" Ch. 1, 1-38. (R. Soc. S. Aust.: Adelaide.)
- GERDES, R. A. (1982) The interpreted depths to magnetic basement map of South Australia. *Q. geol. Notes, geol. Surv. S. Aust.* 83, 2-16.
- GLAESSNER, M. F. (1953) Conditions of Tertiary sedimentation in southern Australia. *Trans. R. Soc. S. Aust.* 76, 141-161.
- & WADDE, M. (1958) St Vincent Basin. In Glaessner, M. F. & Parkin, L. W. (Eds) "The geology of South Australia". *J. geol. Soc. Aust.* 5, 115-126.
- HOWCHIN, W. (1899) Notes on the geology of Kangaroo Island with special reference to evidence of extinct glacial action. *Trans. R. Soc. S. Aust.* 23, 198-207.
- (1903) Further notes on the geology of Kangaroo Island. *Ibid.* 27, 75-90.
- (1918) "The geology of South Australia". First Edition. (Govt. Printer: Adelaide.)
- LINDSAY, J. M. (1969) Cainozoic foraminifera and stratigraphy of the Adelaide Plains Sub-Basin, South Australia. *Bull. geol. Surv. S. Aust.* 42.
- (1970) Melton Limestone: multiple Mid-Tertiary transgressions, southeastern Gawler Platform. *Q. geol. Notes, geol. Surv. S. Aust.* 33, 2-10.
- (1983) Late Eocene to Late Oligocene age of the Kingscote Limestone. *Trans. R. Soc. S. Aust.* 107, this volume.
- & GILES, S. D. (1973) Notes on the *Lepidocyclina* Zone in Morgan Limestone along the Murray River, South Australia. *Q. geol. Notes, geol. Surv. S. Aust.* 45, 1-7.
- LUDBROOK, N. H. (1959) A widespread Pliocene molluscan fauna with *Anodontia* in South Australia. *Trans. R. Soc. S. Aust.* 82, 219-233, pls 1-5.
- (1961) Stratigraphy of the Murray Basin in South Australia. *Bull. geol. Surv. S. Aust.* 36.
- (1963) Correlation of the Tertiary rocks of South Australia. *Trans. R. Soc. S. Aust.* 87, 5-15.
- (1967) Permian deposits of South Australia and their fauna. *Ibid.* 91, 65-87, pls 1-5.
- (1969) Tertiary Period. In Parkin, L. W. (Ed.) "Handbook of South Australian Geology." (Geol. Surv. S. Aust.: Adelaide.)
- (1970) Limestones from the Nullarbor Plain. Appendix to Hiern, M. N. Limestone for railway ballast on the Nullarbor Plain. *Mineral Resour. Rev. S. Aust.* 128, 172-174.
- (1978) Quaternary molluscs of the western part of the Eucla Basin. *Bull. geol. Surv. W. Aust.* 125.
- (1980) "A guide to the geology and mineral resources of South Australia." (Dept. Mines & Energy, South Australia: Adelaide.)
- (1983) Molluscan faunas of the Early Pleistocene Point Ellen Formation and Hurnham Limestone, South Australia. *Trans. R. Soc. S. Aust.* 107, 37-49.
- MCGRAWAN, B. (1978) Early Tertiary foraminiferal biostratigraphy in southern Australia: a progress report. In "The Crespin Volume: essays in honour of Irene Crespin." *Bull. Bur. Miner. Resour. Geol. Geophys. Aust.* 192, 83-95.
- MENAMARA, K. J. & PHILLIP, G. M. (1980) Tertiary species of *Echinolampas* (Echinoidea) from southern Australia. *Mem. Natl Mus. Vict.* 41, 1-14.
- MAJOR, R. H. & VITOIS, V. (1973) The geology of the Vennacher and Horda 1:50 000 Map areas, Kangaroo Island. *Mineral Resour. Rev. S. Aust.* 134, 38-51.
- MILNES, A. R., COOPER, B. J. & COOPER, J. A. (1982) The Jurassic Wisanger Basalt of Kangaroo Island, South Australia. *Trans. R. Soc. S. Aust.* 106, 1-13.
- & HUTTON, J. T. (1983) Calcretes in Australia. In "Soils: an Australian viewpoint," Ch. 10, 119-162. (CSIRO; Melbourne/Academic Press, London.)
- NORTHCOLE, K. H. (1949) Soil survey and land use potential, hundred of Duncan, Kangaroo Island. *Div. Soils CSIRO Aust. Soils and Land Use Series No. 2.*
- (1950) Soil survey of portion of the hundred of Newland, Kangaroo Island, S.A. *CSIRO Aust. Div. Soils, Div. Rep. No. 1/50.*

- (1979) Soils. In Tyler, M. J., Twidale, C. R. & Ling, J. K. (Eds) "Natural History of Kangaroo Island." Ch. 2, 39-46. (R. Soc. S. Aust.: Adelaide.)
- & TUCKER, B. M. (1948) A soil survey of the hundred of Seddon and part of the hundred of MacGillivray, Kangaroo Island. *Bull. Coun. Sci. Indust. Res. Aust.* 233.
- PARR, W. J. (1939) Foraminifera of the Pliocene of South-Eastern Australia. *Min. geol. J.* 1, 65-71.
- PERON, F. (1816) Historical perspective: Kangaroo Island—1803. "Voyage de Decouvertes aux Terres Australes," Vol. II, Ch. XXIV (Translated by J. Fornasiero). In Tyler, M. J., Twidale, C. R. & Ling, J. K. (Eds) "Natural History of Kangaroo Island." Ch. 15, 177-184. (R. Soc. S. Aust.: Adelaide.)
- SINGLETON, O. P., McDUGALL, I. & MALLETT, C. W. (1976) The Pliocene-Pleistocene boundary in southeastern Australia. *J. geol. Soc. Aust.* 23, 299-311.
- SPRIGG, R. C. (1954) Geology of Kangaroo Island. In Sprigg, R. C., Campana, B. & King, D. KINGSCOTE map sheet, Geological Atlas of South Australia 4-mile series. (Geol. Surv. S. Aust.: Adelaide.)
- STUART, W. J. (1970) The Cainozoic stratigraphy of the eastern coastal area of Yorke Peninsula, South Australia. *Trans. R. Soc. S. Aust.* 94, 151-178.
- TATE, R. (1883) The botany of Kangaroo Island, prefaced by a historical sketch of its discovery and settlement and by notes on its geology. *Ibid.* 6, 116-171.
- (1891) A bibliography and revised list of the described echinoids of the Australian Eocene, with descriptions of new species. *Ibid.* 14, 270-282.
- VAIL, P. R. & MITCHUM, R. M. Jnr (1979) Global cycles of relative changes of sea level from seismic stratigraphy. In Watkins, J. S., Montadert, L. & Dickerson, P. W. (Eds) "Geological and geophysical investigations of continental margins." *Mem. Am. Assoc. Petrol. Geol.* 29, 469-472.
- & HARDENBOL, J. (1979) Sea-level changes during the Tertiary. *Oceanus* 22, 71-79.
- WADE, M. (1955) A new genus of the Chapmanininae from southern Australia. *Contr. Cushman Found. foram. Res.* 6, 45-49, pl. 8.
- (1964) Application of the lineage concept to biostratigraphic zoning based on planktonic foraminifera. *Micropaleontology* 10, 273-290, pls 1-2.
- & CARTER, A. N. (1957) The foraminiferal genus *Sherbornina* in southeastern Australia. *Ibid.* 3, 155-164, pls 1-3.
- WADE, A. (1915) The supposed oil-bearing areas of South Australia. *Bull. geol. Surv. S. Aust.* 4.
- WASS, R. E., CONOLLY, J. R. & MACINTYRE, R. J. (1970) Bryozoan carbonate sand continuous along southern Australia. *Marine Geol.* 9, 63-73.

MOLLUSCAN FAUNAS OF THE EARLY PLEISTOCENE POINT ELLEN FORMATION AND BURNHAM LIMESTONE, SOUTH AUSTRALIA

BY N. H. LUDBROOK

Summary

Mollusca of the Point Ellen Formation and Burnham Limestone are recorded and two new species, *Nerita milnesi* and *Linga* (Bellucina) *praetermissa* are described from the Point Ellen Formation. Both formations overlie the Hallett Cove Sandstone or its equivalents. An Early Pleistocene age is indicated from the presence of several species described from the Roe Calcarene, including the pelagic janthinid *Hartungia dennanti chayani*. The Burnham Limestone is considered to be a lateral equivalent of the Point Ellen Formation. Its impoverished fauna contains *Monilea euclensis*, otherwise known only from the Point Ellen Formation and the Roe Calcarene. The relevance of the age of the faunas to the age of tectonic warping on Fleurieu Peninsula and Kangaroo Island is discussed.

MOLLUSCAN FAUNAS OF THE EARLY PLEISTOCENE POINT ELLEN FORMATION AND BURNHAM LIMESTONE, SOUTH AUSTRALIA

by N. H. LUDBROOK*

Summary

LUDBROOK, N. H. (1983) Molluscan faunas of the Early Pleistocene Point Ellen Formation and Burnham Limestone, South Australia. *Trans. R. Soc. S. Aust.* **107**(1), 37-49, 31 May, 1983.

Mollusca of the Point Ellen Formation and Burnham Limestone are recorded and two new species, *Nerita mubesi* and *Linga (Bellucina) praetermissa*, are described from the Point Ellen Formation. Both formations overlie the Hallett Cove Sandstone or its equivalents. An Early Pleistocene age is indicated from the presence of several species described from the Roc Calcarene, including the pelagic janthinid *Hartungia dennanti-chavani*. The Burnham Limestone is considered to be a lateral equivalent of the Point Ellen Formation. Its impoverished fauna contains *Monilea enclensis*, otherwise known only from the Point Ellen Formation and the Roc Calcarene. The relevance of the age of the faunas to the age of tectonic warping on Fleurieu Peninsula and Kangaroo Island is discussed.

KEY WORDS: Mollusca, Early Pleistocene, Point Ellen Formation, Burnham Limestone, new species, Kangaroo Island, Fleurieu Peninsula, tectonism

Introduction

The Point Ellen Formation and its lateral equivalent the Burnham Limestone are thin remnants of carbonate sediments laid down in the Early Pleistocene during a regressive phase which followed a more extensive marine transgression during the Late Pliocene (Ludbrook 1954, 1959). Both formations are of limited extent, at present known to crop out only on the south coast of Kangaroo Island, the eastern side of Gulf St Vincent south of Adelaide and possibly on the Murray River at Tailera Bend. They were deposited on irregular surfaces and vary in thickness from a few centimetres to two metres. At Point Reynolds, Port Willunga and Maslin Bay they occur in sequence above the Hallett Cove Sandstone or its equivalents. Their relative heights above sea level have an important bearing on refining the age of the gentle tectonic folding in the Kangaroo Island-Fleurieu Peninsula elevated zone (Glaessner & Wade 1958).

The richly fossiliferous limestone at Point Ellen on Kangaroo Island has been known since 1914 when, as part of a survey of supposed oil-bearing areas of South Australia, Arthur Wade made the first collection of fossils from the outcrop. Wade's material was sent to Chapman at the National Museum of Victoria for identification and an annotated list of species of foraminifera and Mollusca

was published by Chapman in an Appendix to Wade (1915).

Small collections were made by H. Wopfner in 1964 and A. R. Milnes and B. J. Cooper in 1980. The full significance of the fauna was not recognised until the molluscs were more selectively collected by Milnes, Cooper and Ludbrook in 1981 and by Milnes and Ludbrook in 1982.

Chapman recorded, under the following names and with brief annotations, twelve species: *Glycimeris subardians* Tate (in Basedow), *G. australis* Quoy & Gaimard sp. var. *gigantea* var. nov., *Dosinea* cf. *victoriae* Gatliff & Gabriel, *Tellina basedowi* Tate, *Maetra ovalina* Tate, *Turbo stamineus* Martyn, *Natica conica* Lamarck, *Diastoma* sp., *Litorium verrucosum* Reeve sp., *Voluta (Amorla) undulata* Lamarck sp., *Ancilla* cf. *petterdi* Tate sp. and *Cancellaria granosa* Sowerby.

From recent collecting the fauna has now been increased to 51 species. In the much abridged synonymies of the species accounts Chapman's nomenclature has been included and most of the specimens figured.

The Burnham Limestone was named and described by Firman (1976). Little attention has so far been paid to its small fauna and it is likely that, prior to Brian Dailly's sampling of the formation at Maslin Bay in 1966, any specimen collected from the Burnham Limestone was included in the fauna of the Hallett Cove Sandstone. Dailly's bulk sample was examined as such by Ludbrook without re-

* c/o Department of Mines and Energy, Box 151, Eastwood, South Australia 5063.

covering or naming any of the contained species. It was suggested that the unit might be correlated with sands containing small molluscs occurring at depth at Lockleys and shown on a correlation chart as equivalent to the Pleistocene Calabrian Stage (Ludbrook 1963; Twidale *et al.* 1967). The Hallett Cove Sandstone and Dry Creek Sands were later stated to pass vertically into poorly fossiliferous Lower Pleistocene calcareous or quartz sands in places (Ludbrook 1969). The units were not included in the Cenozoic correlation chart (Ludbrook 1973).

Daily's samples from Maslin Bay and O'Sullivan Beach have now been critically examined, together with material collected by J. M. Lindsay and by Firman and Ludbrook from Firman's supplementary section at Port Willunga. Nine molluscan species are recognised, of which the most important for purposes of correlation is *Monilea euclensis* Ludbrook, described from the Roe Calcareenite and occurring also in the Point Ellen Formation.

Whether they overlie the Hallett Cove Sandstone or not, both the Point Ellen Formation and the Burnham Limestone can be distinguished lithologically from the Late Pliocene Hallett Cove Sandstone by their relative friability and by being less affected by diagenesis. On Kangaroo Island in particular, the Hallett Cove Sandstone is either hard and dense or considerably leached and ferruginised; except at Point Reynolds, the Point Ellen Formation is more porous, less leached and much original shell material is preserved. The matrix may be a soft carbonate rock from which the molluscs weather out readily, as at Cape Jervis. The Burnham Limestone is mostly a soft, powdery, rubbly carbonate rock. Both formations are often affected by surface calcere.

The extent and tectonic implications of the Point Ellen Formation and Burnham Limestone

The Point Ellen Formation was defined by Milnes *et al.* (1983). At present it is known from four exposures only: the type section at Point Ellen at the southwestern entrance to Vivonne Bay, at "Table Rock", Point Reynolds, at the southwestern end of Pennington Bay and Cape Willoughby at the southeastern extremity of Kangaroo Island, and northerly from Cape Willoughby, at Cape Jervis on Fleurieu Peninsula on the eastern side of Backstairs Passage (Fig. 1).



Fig. 1. Locality map.

At "Table Rock", Point Reynolds, the Point Ellen Formation is interbedded with cross-bedded aeolianites near the base of the Bridge-water Formation overlying Late Pliocene limestone. Like the underlying Late Pliocene, the Point Ellen Formation is considerably leached, but it contains *Nerita milnesi*. The boulder from Point Reynolds (GSSA F20/55) formerly thought to have come from the Pliocene is now known to have been derived from the Point Ellen Formation at that locality. It contains *Monilea euclensis*.

Subsequent to its deposition, the Point Ellen Formation has been gently displaced by warping and possibly also by faulting. At Cape Jervis, the base is 50 m above sea level, at Cape Willoughby and Table Rock 10 m above, and at Point Ellen less than 10 m. This gentle warping of less than 1° is considered to be due to reactivation during the Pleistocene of early Palaeozoic tectonic movements in the area, shown by Thomson & Horwitz (1962), and forms part of the broad structural trend from Fleurieu Peninsula to Kangaroo Island (Glaessner 1953).

The Burnham Limestone occurs as thin discrete remnants cropping out south of Adelaide in the sea cliffs or near the coast between Kingston Park and Port Willunga. The most accessible exposure of the Burnham Limestone is in the old boat ramp at Port Willunga, the supplementary section of Firman (1976). Its height above sea level decreases from 30 m at Hallett Cove to 20 m at Maslin Bay. In Aldinga and Maslin Bays the Burnham Limestone conformably overlies the Hallett Cove

Sandstone, and in the southern part of Maslin Bay, where both formations thin out in a northerly direction, the Burnham Limestone persists beyond the northern limit of the Hallett Cove Sandstone. Both formations have a gentle southerly dip of about 1°.

The Burnham Limestone has also been interpreted in bores in the Adelaide Plains Sub-basin as thin patches or lenses of marly limestone overlying a karst surface of the Hallett Cove Sandstone and below the Hindmarsh Clay (Lindsay 1969, Firman 1976, Selby & Lindsay 1982) from Port Gawler southwards, some 52–62 m below sea level on the downthrow side of the Para Fault.

A carbonate sediment containing scattered small gastropods at Jervois punt landing, Tailem Bend, on the Murray River, may possibly be correlated with the Burnham Limestone, but fossil evidence is insufficient.

An outcrop of Hallett Cove Sandstone was formerly exposed at an elevation of 100 m above sea level about 0.5 km east of the type section of the Hallett Cove Sandstone. Although this was mapped (Sprigg 1942) as 'Pleistocene raised beach', the only material collected from the outcrop by Ludbrook and Steel in 1960 belongs to the Hallett Cove Sandstone. No Burnham Limestone was seen, although a remnant occurs about 30 m above sea level near the amphitheatre at Hallett Cove. The difference in elevation of some 60° of the Hallett Cove Sandstone east of Hallett Cove appears to be due to warping rather than faulting at this locality.

The fauna of the Point Ellen Formation

The molluscan fauna is essentially that of a bay with rocky headlands on an exposed coast. A new species, here described as *Nerita milnesi*, is apparently restricted to the formation and is present in considerable numbers. Most nerites live gregariously on rocks in the intertidal zone, although some are adapted to estuarine or even freshwater habitats. Shells of the associated pelagic janthinid gastropod *Hartungia dennanti chavani* have been concentrated with the nerites by on-shore winds in a similar manner to those found in the Roe Calcarenite. The rest of the fauna is an assemblage of both rock-dwelling species and intertidal species of a sandy bay. Of the 51 species, six are restricted to the Early Pleistocene, nine do not occur above the Early Pleistocene and 36 are still living.

Associated with the molluscs is a small assemblage of foraminifera consisting mostly of *Marglinopora vertebralis* and *Ammonia beccarii* with *Flintina triquetra*, *Cribrulinina polystoma*, *Elphidium rotatum* and *Peneropliv* sp. cf. *P. pertusus*.

BIVALVIA

GLYCYMERIDIDAE

Glycymeris (Tucetilla) radians (Lamarck)
Cape Willoughby (1)

Pectunculus radians Lamarck, 1819: 54

A living species recorded from the Late Pliocene and Early Pleistocene.

Glycymeris (Tucetona) convexa (Tate) FIG. 2c. Cape Jervis (1)

Pectunculus convexus Tate, 1886: 138, pl. 11, figs 7a,b

Type locality: Muddy Creek, Victoria, Grange Burn Coquina, Early Pliocene. Tate's type series includes specimens from Norwest Bend Formation and Hallett Cove Sandstone. The species is common in the Dry Creek Sands.

Glycymeris (Veleutacea) pseudaustralis Singleton FIG. 2c,d. Cape Jervis (1)

Glycymeris (Veleutacea) pseudaustralis Singleton, 1941: 425, pl. 20, figs 4, 5

Type locality: Werrikoo Limestone, Glenelg River at Roscoe's, Parish of Killara, Victoria

PECTINIDAE

Chlamys (Chlamys) asperrima asperrima (Lamarck) Cape Jervis (fragment)

Pecten asperimus Lamarck, 1819: 174

A common living species present in the Roe Calcarenite.

Chlamys (Chlamys) asperrima (?) dennanti Gatliff & Singleton Cape Willoughby (3 fragments)

Chlamys asperimus dennanti Gatliff & Singleton, 1930: 73, pl. III, figs 8,9; pl. IV, figs 3a,b

Type locality: Glenelg River above Limestone Creek, Victoria, Werrikooian.

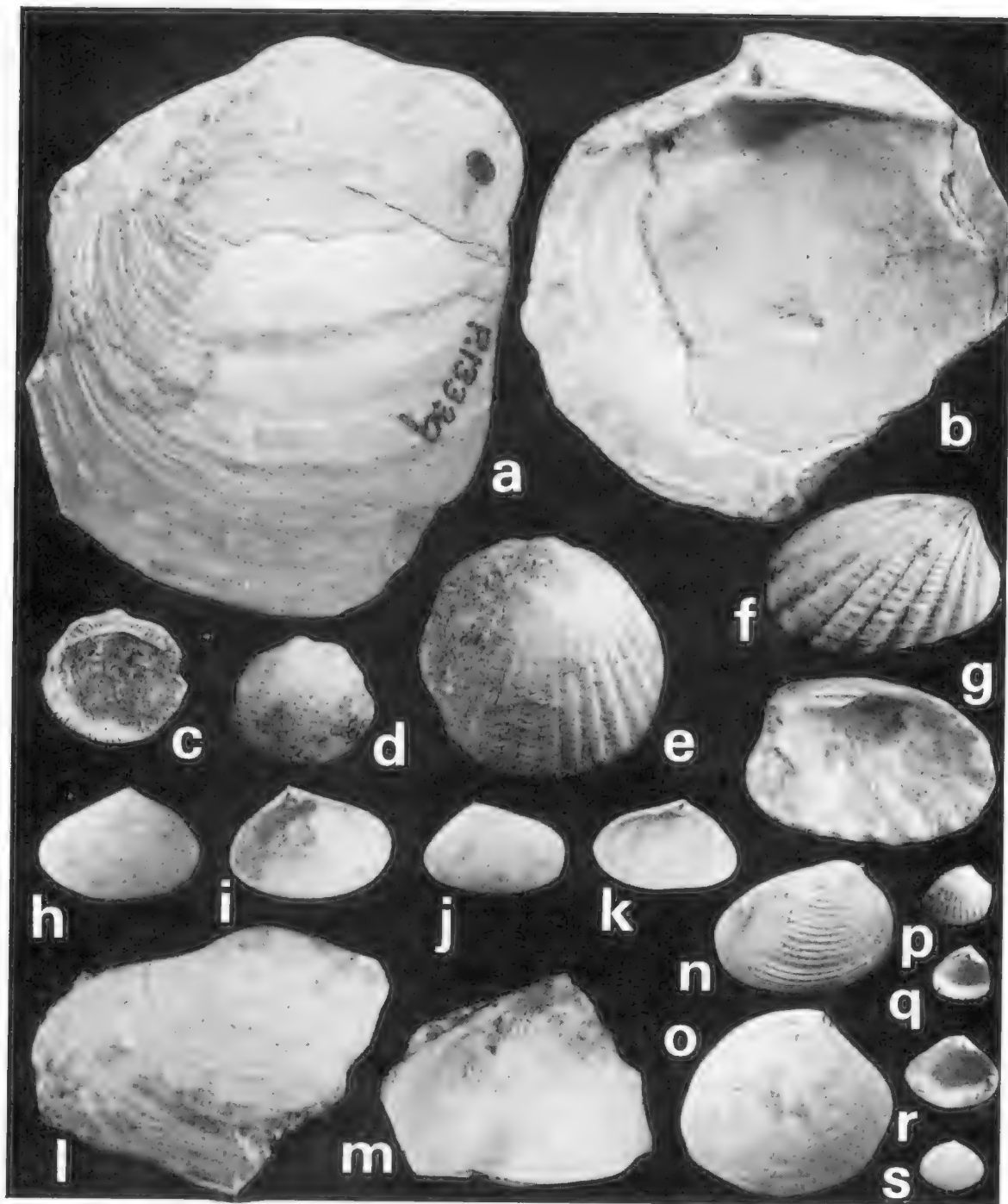
The material is fragmentary and the identification of the sub-species open to doubt. If confirmed, it provides a useful correlation with the Werrikoo Limestone.

OSTREIDAE

Ostrea sp. cf. *Ostrea angasi glenelgensis* Singleton Cape Willoughby (1 fragment), Cape Jervis (1 fragment)

Ostrea angasi Sowerby; Tate, 1887a: 110

Ostrea sinuata glenelgensis Singleton, 1941: 426, pl. 20, fig. 6



Two fragments of valves of a rounded species with a straight dorsal margin, long hinge and large muscle scar appear to belong to the subspecies, described from the basal shell bed of the Werrikoo Limestone and recorded as occurring at a higher level with

Pecten meridionalis, i.e. Late Pliocene to Early Pleistocene.

LUCINIDAE

Anodontia sphericula (Basedow) FIG. 2a
Point Ellen (5)

Meretrix sphericula Basedow, 1902: 131, pl. 2, fig. 2

Glycymeris australis Quoy & Gaimard sp. var. *gigantea* Chapman, 1915: 49; Chapman & Singleton, 1925: 47, pl. III, fig. 32; pl. IV, fig. 22. *Anodontia sphericula* (Basedow) Ludbrook, 1959: 227, pl. 3, figs 1-3, pl. 5, figs 1-4; 1973: pl. 26, fig. 65; 1978: 52, pl. 5, fig. 1

Singleton (1941, 426) noted that the holotype of *Glycymeris australis* var. *gigantea* (here refigured) was, in his opinion, not a glycymerid but a lucinid.

The species has a long range from Miocene to Early Pleistocene.

Miltha hamptonensis Ludbrook FIG. 2b Point Ellen (6), Cape Jervis (1)

Dosinia cf. *victoriae* Chapman, 1915: 49, non Gatliff & Gabriel

Miltha hamptonensis Ludbrook, 1969: 60, pl. 3, figs 1-3; pl. 4, figs 1, 2

Otherwise known only from the Roe Calcarenite.

?*Callucina lacteola* (Tate)

Lucina lacteola Tate, 1897: 48 nom. nov. for *Lucina lactea* Adams non Lamarck.

A mould in limestone from Point Reynolds may be referred to this living species which occurs also in the Roe Calcarenite.

Genus *Linga* de Gregorio, 1884

Subgenus *Bellucina* Dall, 1901

Linga (*Bellucina*) *praetermissa* sp. nov.

FIG. 3a-d

Bellucina crassilirata Macpherson & Gabriel, 1962: 327, fig. 372, non Tate, 1887

Material: Holotype GSSA 10020 and two paratypes GSSA 10021 Point Ellen Formation, Point Ellen; numerous valves SAM labelled "*Lucina crassilirata* Tate, Kenyon Collection, probably Victoria". The uncertainty of the locality precludes selection of types from the Victorian material.

Shell small, solid but only moderately thick, globose, subequilateral, rounded anteriorly, posteriorly truncated, with an umbonal-ventral flexure, margin sinuated at flexure; sculpture

variable, predominantly of fine concentric lirae, interrupted by deep growth channels; radial sculpture variable or absent, consisting of fine threads crossing interspaces between the concentric lirae; inner margin finely crenulate. Hinge of moderate width, cardinals oblique with triangular pit between them, LV with 4b narrow, high, 2 triangular, short, PII, PIV, AII, AIV all short; RV with small 3a, triangular somewhat bifid 3b, short AI, AIII, PI, and PIII. Holotype height 7, width 7 mm; paratype (locality "Victoria") height 10, width 10 mm.

The species figured by Macpherson & Gabriel as *Bellucina crassilirata* was stated to be seen frequently at Western Port.

CARDITIDAE

Cardita subdeceptiva Ludbrook FIG. 2f,g Cape Jervis (3)

Cardita subdeceptiva Ludbrook, 1955: 40, pl. 3, fig. 14

Known also from the Dry Creek Sands and the Late Pliocene of Gum Creek, K.I.

Pleuromeris subpecten Ludbrook FIG. 2p,q Cape Jervis (2)

Pleuromeris subpecten Ludbrook, 1955: 42, pl. 2, fig. 3

Described from the Dry Creek Sands

MACTRIDAE

Maetra sp. cf. *Maetra pura* Deshayes

Maetra pura Deshayes, 1853: 15

An internal cast of a *Maetra*, similar in shape to *M. pura*, recorded (Ludbrook 1978) from Early Pleistocene to Holocene.

MESODESMATIDAE

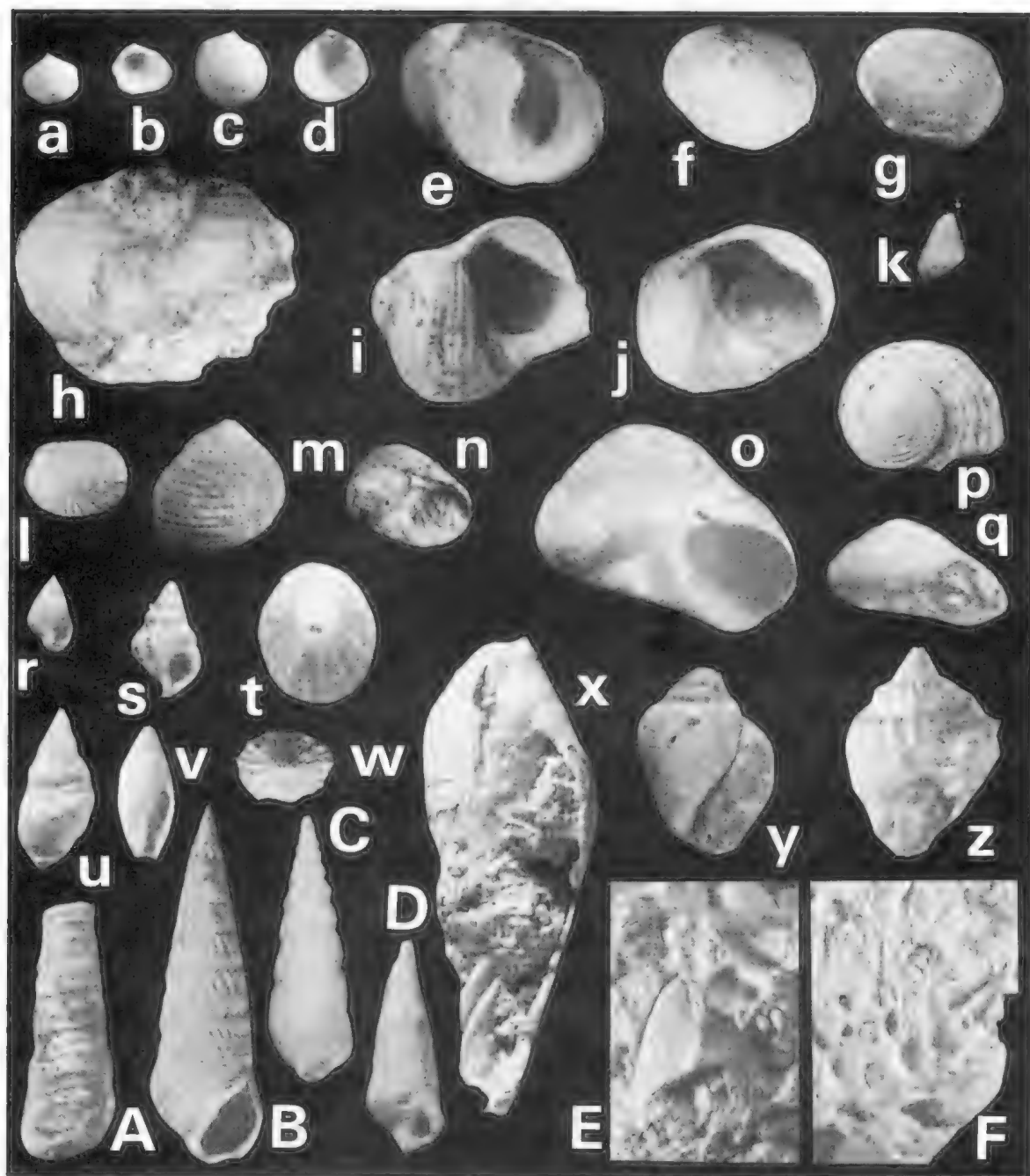
Amesodesma angusta (Reeve) FIGS 2j,k Point Ellen (3)

Mesodesma angusta (Reeve) 1854 pl. 1, fig. 3

Occurs rarely in the Point Ellen Formation and, like *A. cuneata*, has a continuous record on Kangaroo Island from the Early Pleistocene to the present.

Fig. 2. a. *Anodontia sphericula* (Basedow), holotype of *Glycymeris australis gigantea* Chapman NMV P13339; b. *Miltha hamptonensis* Ludbrook GSSA 10009; c,d. *Glycymeris* (*Veletucta*) *pseudaustralis* Singleton c. interior, d. exterior GSSA 10010; e. *G. (Tuctoma) convexa* (Tate) GSSA 10011; f,g. *Cardita subdeceptiva* Ludbrook RV f. exterior, g. interior GSSA 10012; h,i. *Amesodesma cuneata* (Lamarck) LV h. exterior, i. interior GSSA 10013; j,k. *Amesodesma angusta* (Reeve) RV j. exterior, k. interior GSSA 10014; l,m. *Fellina* sp. (*Maetra ovalina* of Chapman) GSSA 10015; n. *Katelysia scalarina* (Lamarck) GSSA 10016; o. *Galrarium perornatum* Woods GSSA 10017; p,q. *Pleuromeris subpecten* Ludbrook GSSA 10018; r. s. *Timoclea* (*Veremolpa*) *kendricki* Ludbrook LV r. interior, s. exterior GSSA 10019. All natural size and all from Point Ellen except m,n,r,s from Cape Jervis.

GSSA, Geological Survey of South Australia; NMV, National Museum of Victoria; SAM, South Australian Museum



The subgenus *Amesodesma* is here accorded full generic status, details of which are discussed in a paper in preparation.

Amesodesma cuneata (Lamarck) FIG. 2h,i. Point Ellen (3)

Crassatella cuneata Lamarck 1818: 483

Specimens from Point Ellen are identical with living specimens from Kingscote and with

those occurring in the St Kilda Formation of the coast road, Bay of Shoals. The species is more common on Kangaroo Island than the smaller, narrower *A. angusta*.

TELLINIDAE

Tellina sp. FIG. 2o,p. Point Ellen (3)

Macra ovalina Lamarck. Chapman 1915: 49, non *Macra ovalina* Lamarck

The specimens identified as *Maetra ovalina* are in the Palaeontology Collection of the Geological Survey of South Australia, together with another specimen collected by H. Wopfner in 1964. With two exceptions, they are firmly embedded in hard matrix and the hinges are obscured. Although in shape and size they are comparable with the New Zealand *Longimaetra elongata* (Quoy & Gaimard), no suggestion of a maetrid hinge can be seen. There is a long external ligament pit and a supporting nymph; such of the pallial line as is visible appears to have a fairly deep sinus. The species is therefore probably a large *Tellina* with rather convex valves.

VENERIDAE

Katelysia scalarina (Lamarek) FIG. 21 Point Ellen (7), Point Reynolds (moulds), Cape Willoughby (mould)

Venus scalarina Lamarek, 1818: 599

Not uncommon in the formation, as in the Roe Calcarene and throughout the Pleistocene to the present.

Timoclea (Veremolpa) kendricki Ludbrook FIG. 2rs. Point Ellen (1), Cape Willoughby (1)

Timoclea (Veremolpa) kendricki Ludbrook 1978: 80, pl. 9, figs 9-12, 15, 16.

Described from the Roe Calcarene.

Gafrarium perornatum Woods FIG. 2q Point Ellen (1)

Gafrarium perornatum N. H. Woods, 1931: 148, pl. 7, figs 7, 8

Occurs in the Dry Creek Sands and is otherwise known only from Point Ellen.

SCAPHOPODA

DENTALIIDAE

Dentalium latesulcatum Tate Cape Jervis (1)

Dentalium latesulcatum Tate, 1899: 262, 267, pl. 8, fig. 9

Has a range of Early Pliocene to early Pleistocene

GASTROPODA

HALIOTIDAE

Haliotis (Exohaliotis) cyclobates Peron & Lesueur Point Ellen (2 fragments)

Haliotis cyclobates Peron & Lesueur, 1816: 80

Found also in the Roe Calcarene but otherwise known only from the modern fauna.

FISSURELLIDAE

Clypidina (Montfortula) rugosa (Quoy & Gaimard) FIG. 31 Point Ellen (1), Cape Jervis (1)

Emarginula rugosa Quoy & Gaimard, 1834: 331, pl. 68, figs 17, 18

Previously known only from the modern fauna.

ACMAEIDAE

Patelloida nigrosulcata (Reeve) Point Ellen (1)

Patella nigrosulcata Reeve, 1855: pl. 30, fig. 84

First appears in the Point Ellen Formation and continues through the Glanville and St Kilda Formations to the present day, when it is commonly found attached to *Patella (Scutellastra) laticostata* Blainville.

PATELLIDAE

Patella (Scutellastra) peronii Blainville FIG. 31, Cape Jervis (2)

Patella peronii Blainville, 1825: 111

Known only from Cape Jervis and the modern fauna.

TROCHIDAE

Cantharidus (Phasianotrochus) eximius (Perry) Point Ellen (3)

Bullmus eximius Perry, 1811: pl. 30, fig. 20

Previously known only from the modern fauna.

Fig. 3, a-d. *Linga (Bellucina) praetermissa* sp. nov. a, b, holotype LV a, exterior, b, interior GSSA 10020, c, d, Kenyon specimen SAM RV c, exterior, d, interior; e-g. *Nerita milnesi* sp. nov. e, holotype apertural view GSSA 10022, f, g, paratypes showing variation in ribbing GSSA 10023, h-j. *Hartungia denhami chavani* Ludbrook GSSA 10025 a, b, c; k. *Cantharidus (Phasianotrochus) apicinus* (Menke) GSSA 10026; l. *Clypidina (Montfortula) rugosa* (Quoy & Gaimard) GSSA 10027; m, n. *Diloma (Fracturmillia) conamerata* (Wood) GSSA 10028; o. *Diloma (Fracturmillia) rudis* (Gray) GSSA 10029; p, q. *Monilea euclensis* Ludbrook p, apical view GSSA 10030, q, apertural view GSSA 10031; r. *Niotoha pyrrhus* (Menke) GSSA 10032; s. *Cymatella verrucosa* (Reeve) Chapman specimen GSSA 10033; t. *Patella (Scutellastra) peronii* Blainville GSSA 10034; u. *Cominella eburnea* (Reeve) GSSA 10035; v. *Amalda (Gracilispira) monilifera* (Reeve) GSSA 10036; w. *Siphonaria (Hubendiekula) baconi* Reeve GSSA 10037; x. *Amoria (Amoria) grayi* Ludbrook GSSA 10038; y. *Austroharpa kendricki* Ludbrook GSSA 10039; z. *Sydaphera undulata* (Sowerby) GSSA 10040; A. *Gazameda fredalei* Finlay GSSA 10041; B. *Diastoma adelaidense* Ludbrook GSSA 10042; C. *D. melanioides* (Reeve) GSSA 10043; D. Burnham Limestone with cast of *Brachidontes* sp. cf. *B. suberosus* (Singleton) GSSA 10044; E. Burnham Limestone with moulds and casts of *Batillaria (Batillariella) estuarina* (Tate) GSSA 10045. All natural size and from Point Ellen except k, q, v. E and F from Burnham Limestone.

Diloma (Fractarmilla) concamerata (Wood) FIG. 3m,n. Point Ellen (5). Cape Jervis (29)

Trochus concamerata Wood, 1828: 17, pl. 6, fig. 35

The earliest record is in the Point Ellen Formation; it continues through the Glanville and St Kilda Formations to the present day. *Diloma (Fractarmilla) rudis* (Gray) FIG. 3o. Point Ellen (1)

Monodonta rudis Gray, 1827: 480

Occurs rarely in the Point Ellen and Glanville Formations of Kangaroo Island and in the modern fauna west from Gulf St Vincent to Western Australia where it is common.

Monilea euclensis Ludbrook FIG. 3p,q. Point Ellen (3), Cape Jervis (2)

Monilea euclensis Ludbrook, 1978: 97, pl. 10, figs 4-8, 12

Described from the Roe Calcarene where it is common; elsewhere known only from the Point Ellen Formation where it appears to be not uncommon, and the Burnham Limestone.

TURBINIDAE

Turbo (Ninella) torquatus Gmelin. Point Ellen (2), Cape Jervis (1)

Turbo torquatus Gmelin, 1791: 3597, No. 106
Turbo stamineus Martyn. Chapman, 1915: 49 (Martyn name rejected ICZN 456)

The three small examples are the earliest certain record of the species which continues through uncommon occurrences in the Glanville Formation to the present day.

Astraea (Microastraea) aurea (Jonas) Point Ellen (1).

Trochus aureus Jonas, 1845: 168

The living species occurs also in the Glanville Formation on Kangaroo Island.

Astraea (Microastraea) rutidoloma (Tate) Cape Jervis (3)

Turbo (Astrallum) rutidoloma Tate, 1893: 192, pl. 1, fig. 9

Common in the Roe Calcarene but not so far recorded from the Late Pleistocene; living.

NERITIDAE

Genus *Nerita* Linnaeus, 1758

Nerita milnesi sp. nov.

FIG. 3e-g.

Material: holotype GSSA 10022 and paratypes GSSA 10023, 10024 61 topotypes Point Ellen, 1 specimen and 3 fragments Cape Willoughby, 65 specimens Cape Jervis.

Shell rather small, globose, solid, thick, spire flat, almost obliquely planispiral, (the

inner walls of Neritidae being resorbed), protoconch flat, usually eroded, 1-14 adult whorls, the last whorl almost enveloping the rest of the shell; surface of shell sculptured with 24-27 spiral ribs with linear grooves between them. Ribs generally light coloured and grooves black, protoconch smooth and white. Aperture semicircular, outer lip crenulated by spiral ribs, widely thickened with posterior denticle and anterior denticle set on inner margin of lip, inner lip septum or "deck" well developed, smooth and shining with three denticles in the middle.

Dimensions: holotype height 12, diameters 23 and 18 mm; large paratype height 16, diameters 24 and 20 mm.

The species resembles most closely *Nerita lineata* from northwest and northern Australia. It is only about half the size of *lineata*, which is generally more finely ribbed and somewhat more variable than *N. milnesi*, specimens from Exmouth being closer to *N. milnesi* than those from the north. It is extremely abundant in the cliff face at Point Ellen, forming a coquina in places, and was no doubt living gregariously on rocks in the intertidal zone like its modern counterparts. It has gone unnoticed in the past, with the exception of a reference to "Reef shell beds (*Turbo* etc.) at the base of the aeolianite system" in the Pleistocene section of the legend to the KINGSCOTE 4-mile geological series map (Sprigg 1954).

The species is named for Dr A. R. Milnes.

PHASIANELLIDAE

Phasianella angasi Crosse

Phasianella angasi Crosse, 1864: 344, pl. 13, fig. 5

A single specimen was found at Point Ellen and a doubtful specimen in the Holocene at Point Tinline. Modern distribution of the species is from Western Australia to South Australia.

Phasianella australis (Gmelin) Point Ellen (9)

Buccellum australe Gmelin, 1791: 3490, No. 173

Appears to be common in the Point Ellen Formation as it is in the Roe Calcarene. Its first known occurrence is in the Late Pliocene at Gum Creek and it persists through the Glanville Formation to the present day.

LITTORINIDAE

Bembicium melanostoma (Gmelin) Point Ellen (2)

Trochus melanostomus Gmelin, 1791: 3581

Has a continuous record from the Early Pleistocene to the present day, when it lives mostly in sheltered rocky bays or on mud flats.

Bembicium nanum (Lamarck) Cape Jervis (9)

Trochus nanum Lamarck, 1822b: 30

Has an irregular record in the Quaternary. It occurs in the Roe Calcareenite and in the Glanville and St Kilda Formations on Kangaroo Island. It is a modern inhabitant of rocks on open coast.

POTAMIDIDAE

Batillaria (*Zacumantus*) *diemenensis* (Quoy & Gaimard) FIG. 3D, Point Ellen (21)

Cerithium diemenense Quoy & Gaimard, 1833: Atlas pl. 55, figs 11-13; 1834: 128.

Occurs more or less abundantly from the Late Pliocene of the Dry Creek Sands to the present day.

TURRITELLIDAE

Guzameda *iredalei* Finlay FIG. 3A, Point Ellen (3)

Guzameda iredalei Finlay, 1927: 496.

First appears in the Dry Creek Sands, very common in the Roe Calcareenite and continuing through the Glanville Formation and St Kilda Formation to the present day.

DIASTOMATIDAE

Diastoma adelaidense Ludbrook FIG. 3B, Point Ellen (6)

Diastoma adelaidense Ludbrook, 1971: 32, pl. 1, figs 3-7, pl. 6, figs 9, 10

Diastoma melanioides (Reeve) FIG. 3C, Point Ellen (13), Point Reynolds, Cape Willoughby (moulds)

Mesalia melanioides Reeve, 1849: pl. 1, fig. 1.

Diastoma sp. Chapman 1915: 49

Chapman noted that the *Diastoma* in Wade's material was closely related to *D. provisi* Tate from Hallett Cove and the Dry Creek Bore; both *D. adelaidense* and *D. melanioides* are present, however, as they are also in the Roe Calcareenite.

CERITHIIDAE

Diala latta A. Adams Point Ellen (2)

Diala latta A. Adams, 1862: 298

This is a ubiquitous small species throughout the Quaternary, although uncommon at Point Ellen where the environment would have been rather unfavourable. It lives today on algae in sheltered inlets and bays.

Campanile symbolicum Iredale Point Ellen (1)

Campanile symbolicum Iredale, 1917: 326 *nom. nov.* for *Cerithium leve* Quoy & Gaimard, 1833 *non Cerithium laevis* Perry, 1810

Represented in the Point Ellen Formation by a single specimen embedded in hard matrix with coral. This is as far east as the species has been found. It is common in the Roe Calcareenite and in the modern Western Australian fauna.

IANTHINIDAE

Hartungia denhami chavani FIG. 3h-j, Point Ellen (17), Cape Jervis (4)

Hartungia denhami chavani Ludbrook, 1978: 119, pl. 12, figs 1-14

From a stratigraphic point of view, this is the most diagnostic and important species in the Point Ellen Formation. It is a pelagic gastropod with a limited range, found abundantly in the Roe Calcareenite. In the Point Ellen Formation it was probably brought in by on-shore winds and deposited in some abundance with *Nerita* at the type section.

HIPPONICIDAE

Hipponix (*Sabia*) *conicus* (Schumacher), Point Reynolds (moulds), Cape Jervis (1)

Amalthea conica Schumacher, 1817: 181, pl. 21

Represented by a single specimen only from Cape Jervis. It has a range of Late Pliocene to the present.

Hipponix (*Antisabia*) *erma* (Cotton), Point Ellen (1), Point Reynolds (mould), Cape Jervis (1)

Sabia (*Antisabia*) *erma* Cotton, 1939: 171, pl. 7, fig. 8

Described from Reevesby Island. The specimen from Point Ellen is small with somewhat granulose concentric laminae approaching the sculpture of *H. (A.) foliaceus*. However, in both this specimen and the more typical example of *H. (A.) erma* from Cape Jervis, as well as the mould from Point Reynolds, the apex nearly overhangs the margin. Also occurs in the Glanville Formation.

NAUSICIDAE

Polinices (*Conuber*) *conicus* (Lamarck) Point Ellen (1)

Natica conica Lamarck, 1822a: 198

Natica conica Lamarck, Chapman 1915: 49

The species has an almost continuous record from the Late Pliocene to the present.

CYMATIIDAE

Cymatella verrucosa (Reeve) FIG. 3s, Point Ellen (1)

Triton verrucosus Reeve, 1844: pl. 17, sp. 71
Litorium verrucosum Reeve sp. Chapman, 1915: 49

The record is limited to the single specimen identified by Chapman; it is a living species occurring also in the Glenville and St Kilda Formations.

BUCCINIDAE

Cominella eburnea (Reeve) FIG. 3u. Point Ellen (5)

Buccinum costatum Quoy & Gaimard, 1833: 417, pl. 30, figs 17-26 (non Linnaeus, 1758, nec Da Costa 1778, nec Meuschen, 1787) *Buccinum eburneum* Reeve, 1846: sp. 31, pl. 12, fig. 93

Represented continuously from the Point Ellen Formation and Roe Calcarene to the present day.

NASSARIIDAE

Niotha pyrrhus (Menke) FIG. 3r. Point Ellen (3)

Buccinum pyrrhus Menke, 1843: 21

Has a continuous record from the Roe Calcarene and Point Ellen Formation to the present

OLIVIDAE

Amalda (Gracilispira) monilifera (Reeve) FIG. 3v. Point Ellen (24)

Ancillaria lineata Kiener, 1844: 16, pl. 3, fig. 2 non *Ancilla lineata* Perry, 1811

Ancillaria monilifera Reeve, 1864: v.10, figs 36a,b

Ancilla cf. *petterdi* Tate sp. Chapman 1915: 50

This living species is common in both the Roe Calcarene and Point Ellen Formation but is not known so far from the Late Pleistocene.

VOLUTIDAE

Amoria (Amoria) grayi Ludbrook FIG. 3x. Point Ellen (1)

Voluta pallida Gray, 1834: pl. 30, fig. 4, Index p. 601 (non *Voluta pallidus* Linnaeus, 1767)

Voluta (Amoria) undulata Chapman, 1915: 50 (non *Voluta undulata* Lamarck)

Amoria (Amoria) grayi Ludbrook, 1953 nom. nov. for *Voluta pallida* Gray non Linnaeus not *Amoria grayi* Daily et al. 1976

Chapman recorded two species of *Voluta (Amoria) undulata* having considerable variation in the height of the spires. Only the specimen figured here is in the GSSA collection and

although it is incomplete it can be fairly reliably compared with *Amoria (Amoria) grayi*. It has no trace of the undulose linear surface ornament of *undulata* noted by Chapman. The specimen figured by Daily et al. (1976, fig. 21b) as *Amoria grayi* is not that species but a specimen in the Tate Museum, University of Adelaide, identified as *Amoria masoni* (Tate).

A. (A.) grayi was recorded also from the Dry Creek Sands and the Roe Calcarene. It is a common variable species with a modern range from Geographie Bay to Cambridge Gulf, W.A.

CANCELLARIIDAE

Sydaphera undulata (Sowerby) FIG. 3z. Point Ellen (1)

Cancellaria granosa Sowerby, 1832: pl. 10, fig. 16 (not pl. 10, fig. 17)

Cancellaria undulata Sowerby, 1848: 136

Cancellaria granosa Sowerby, Chapman, 1915: 50

Only one of the two specimens recorded by Chapman is in the GSSA Collection. Rare in the Point Ellen Formation and the Roe Calcarene and is not known again before its present occurrence from southwestern Australia to Victoria.

CONIDAE

Conus sp. Cape Willoughby (1)

An internal cast of an unidentified *Conus* embedded in matrix occurs at Cape Willoughby.

SIPHONARIIDAE

Siphonaria (Huhendickula) baconi Reeve FIG. 3w. Point Ellen (1)

Siphonaria baconi Reeve, 1856: pl. 6, sp. 30

A single specimen was found among the material examined by Chapman.

Has a continuous range in South Australia from the Point Ellen Formation to the present.

The fauna of the Burnham Limestone

The Burnham Limestone contains molluscan species most of which are intertidal inhabitants of estuaries, tidal inlets, or the sandy or muddy flats of sheltered bays. The small assemblage is dominated by *Batillaria* (*Batillariella*) *estuarina* and *Anapella variabilis*, with *Chlamys* (*Equichlamys*) *bifrons subbifrons*, *Brachidontes* sp. cf. *B. suberosus*, *Limatula* sp. cf. *L. ludbrookae*, *Cantharidus* (*Phasianotrochus*) *apicinus*, *Monilea euclensis*, *Microcolus dunkeri* and *Austrorhapa kendricki*.

Three species are restricted to Early Pleistocene deposits, one occurs also in the Late Pliocene and the rest are still living.

Marginapora vertebralis is also present.

BIVALVIA

PECTINIDAE

Chlamys (*Equichlamys*) *bilfrons subbilfrons* (Tate) Maslin Bay (1)

Pecten subbilfrons Tate, 1882: 44; 1886: 104, pl. 3, fig. 2.

The specimen is poorly preserved but appears to belong to the subspecies.

MYTILIDAE

Brachidontes sp. cf. *B. suberosus* (Singleton) FIG. 3E. Maslin Bay (1)

Aulacomya suberosa Singleton, 1941: 427, pl. XX, fig. 7

Represented by an internal cast only, but the straight anterior margin, sharp ridge and acute beaks are clearly seen. The only other recorded occurrence is in the Werrikoo Limestone of Limestone Creek, Glenelg River, Western Victoria.

LIMIDAE

Limatula ludbrookae Buonaiuto Maslin Bay (1)

Limatula ludbrookae Buonaiuto, 1977: 28, figs 1, 10-11, 27-35

The only specimen found so far is an internal mould which has the distinctive high, narrow shape of the species. It has been known previously only from the Hallett Cove Sandstone and Dry Creek Sands.

MESODESMATIDAE

Anapella variabilis (Tate) Maslin Bay (common), Port Willunga (8)

Anapa variabilis Tate, 1887b: 172, pl. 17, figs 5a-b

Modern relatives of this species inhabit estuaries and shallow water. The species is abundant in patches in the Burnham Limestone, mainly in the form of internal casts. It has a range of Late Pliocene to Early Pleistocene.

GASTROPODA

TROCHIDAE

Cantharidus (*Phasianotrochus*) *apicinus* (Menke) O'Sullivan Beach (1)

Monodonta apicina Menke, 1843: 15

Rare in the Burnham Limestone, but occurs abundantly in the Roe Calcarene and in the Holocene.

Monilea euclensis Ludbrook Hallett Cove (1), O'Sullivan Beach (1)

Monilea euclensis Ludbrook, 1978: 97, pl. 10, figs 4-8, 12

Known only from the Roe Calcarene, Point Ellen Formation and the Burnham Limestone.

POTAMIDIDAE

Batillaria (*Batillariella*) *estuarina* (Tate) FIG. 3F Maslin Bay (abundant)

Bittium estuarinum Tate, 1893: 190, pl. 1, fig. 12

As the name implies, the species occurs in estuaries and tidal inlets. It is abundant in the Burnham Limestone at Maslin Bay. It has a continuous record from the Early Pleistocene to the present.

FASCIOLARIIDAE

Microcolux dunkeri (Jonas) Maslin Bay (1)

Fusus dunkeri Jonas, 1846: 129

Has a continuous record from the Early Pleistocene to the present, but is rare in the Burnham Limestone.

HARPIDAE

Austroharpa kendricki Ludbrook FIG. 3y. Hallett Cove (1)

Austroharpa kendricki Ludbrook, 1978: 162, pl. 18, figs 4-6

An internal cast from Hallett Cove appears to belong to the variety of the species with a denticulate outer lip (Ludbrook 1978, pl. 18, fig. 6) and a very low spire. The species is otherwise known only from the Roe Calcarene. *Austroharpa* is well represented in the Tertiary of southern Australia and is still surviving off the coast today in relatively shallow water.

Acknowledgments

I am greatly indebted to my colleagues whose assistance in collecting material made this study possible: Drs A. R. Milnes, B. J. Cooper and B. Daily; the field party from the Geological Survey of South Australia, particularly A. Crooks; J. B. Firman. I wish also to thank the National Museum of Victoria for the loan of the type of *Glycymeris australis gigantea* Chapman, the Drafting Branch of the Department of Mines and Energy for drawing the locality map, and the Director-General of Mines and Energy for permission to publish.

References

- ADAMS, A. (1862) On the animal and affinities of the genus *Alaba* with a review of known species, and description of some new species. *Ann. Mag. Nat. Hist.* ser. 3, **10**, 293-299.
- BASEDOW, H. (1902) Descriptions of new species of fossil Mollusca from the Miocene limestone near Edithburg. *Trans. R. Soc. S. Aust.* **26**(2), 130-132, pl. 2.
- BEU, A. G. (1971) Genera of the bivalve family Mesodesmatidae, with comments on some Australasian species. *J. malac. Soc. Aust.* **2**(2), 113-131.
- BLAINVILLE, H. M. D., DE (1825) *Manuel de Malacologie et de Conchyliologie*. Paris, Strasbourg.
- BUONAIUTO, M. F. (1977) Revision of the Australian Tertiary species ascribed to *Limatula* Wood (Mollusca, Bivalvia). *Trans. R. Soc. S. Aust.* **101**(1), 21-33.
- CHAPMAN, F. (1915) Report on a collection of fossils made by Dr A. Wade from the Cainozoic series of South Australia. Appendix II In Wade, A. The supposed oil-bearing areas of South Australia. *Bull. geol. Surv. S. Aust.* **4**, 44-50.
- & SINGLETON, F. A. (1925) A revision of the Cainozoic species of *Glycymeris* in southern Australia. *Proc. R. Soc. Vict.* **37**(1) n.s., 18-60, pls 1-4.
- COTTON, B. C. (1939) Sir Joseph Banks Islands. Part 2, Mollusca. *Ibid.* **51**(1), 159-176, pl. 7.
- CROSSE, H. (1864) Description d'espèces nouvelles provenant de l'Australie méridionale. *J. Conchyl.* **12**, 339-346, pl. 13.
- DESHAYES, G. P. (1853) Descriptions of fourteen new species of *Macra* in the collection of Mr Cuming. *Proc. zool. Soc.* **XXI**, 14-17.
- FIRMAN, J. B. (1976) Limestone at the base of the Pleistocene sequence in South Australia. *Quart. Geol. Notes, Geol. Surv. S. Aust.* **58**, 1-5.
- GATLIFF, J. H. & SINGLETON, F. A. (1930) On the relationship between "*Pecten*" *asperimus* Lamarck and "*Pecten*" *antiaustralis* Tate, with a description of an allied fossil form. *Proc. R. Soc. Vict.* **42**(2) (n.s.), 71-77.
- GLAESSNER, M. F. (1953) Some problems of Tertiary geology in southern Australia. Clarke Memorial Lecture. *J. Proc. R. Soc. N.S.W.* **87**(2), 31-45.
- & WADE, M. (1958). St Vincent Basin. In Glaessner, M. F. & Parkin, L. W. (eds) *The geology of South Australia*. *J. geol. Soc. Aust.* **5**(2), 115-126.
- GMELIN, J. F. (1791) *Linnaeus Systema naturae ... ed XIII aucta reformata*, 3021-3910. Lipsiae.
- GRAY, J. E. (1827) In King, P. P. Narrative of a survey of the intertropical and western coasts of Australia. Appendix B. Mollusca. vol. 2, 474-496. (J. Murray: London.).
- INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE (1958) Official Index of rejected and invalid works in Zoological Nomenclature. Opinion 456.
- JONAS, J. H. (1845) Neue Trochoideen. *Zeits. für Malakozoologie* for the year 1844, 167-172 (Nov. 1844).
- (1846) *Molluskologische Beiträge. Abh. Naturw. Ver. Hamburg.* **1**, 101-130, pls 7-11.
- KIENER, L. C. (1843-1844) *Ancillaria. Species général et Iconographie des coquilles vivantes ... I*. Paris 1834-1880.
- LAMARCK, J. B. P. A. DE M. (1818) *Histoire naturelle des animaux sans vertèbres* (Paris). **5**.
- (1819) *Ibid.* **6**(1).
- (1822a) *Ibid.* **6**(2).
- (1822b) *Ibid.* **7**.
- LINDSAY, J. M. (1969) Cainozoic foraminifera and stratigraphy of the Adelaide Plains Sub-basin, South Australia. *Bull. geol. Surv. S. Aust.* **42**.
- LUDBROOK, N. H. (1953) Systematic review of the volutid genus *Amoria*. *Proc. malac. Soc. Lond.* **30**, 131-153.
- (1954) The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part 1. *Trans. R. Soc. S. Aust.* **77**, 42-64.
- (1955) *Ibid.* Part 2. *Ibid.* **78**, 18-87, pls. 1-6.
- (1959) A widespread Pliocene molluscan fauna with *Anodontia* in South Australia. *Ibid.* **82**, 219-233, pls 1-5.
- (1963) Correlation of the Tertiary rocks of South Australia. *Ibid.* **87**, 5-15.
- (1969a) Tertiary Period. In Parkin, L. W. (ed.) "*Handbook of South Australian geology*". (Geol. Surv. S. Aust.: Adelaide.)
- (1969b) The genus *Miltha* (Mollusca: Bivalvia) in the Australian Cainozoic. *Trans. R. Soc. S. Aust.* **93**, 55-63, pls. 1-5.
- (1971) Large gastropods of the families Diastomatidae and Cerithiidae (Mollusca: Gastropoda) in southern Australia. *Ibid.* **95**(1), 29-42, pls 1-6.
- (1973) Distribution and stratigraphic utility of Cenozoic molluscan faunas in southern Australia. *Sci. Rep. Tohoku Univ.* 2 ser. Spec. vol. **6**, 241-261, pls. 24-28.
- (1978) Quaternary molluscs of the western part of the Eucla Basin. *Bull. geol. Surv. W. Aust.* **125**.
- MACPHERSON, J. H. & GABRIEL, C. J. (1962) "*Marine molluscs of Victoria*". (Melbourne University Press & National Museum of Victoria: Melbourne).
- MENKE, C. T. (1843) *Molluscorum Novae Hollandiae ... (Hannoverae in libraria aulica Hahniana Hannoverae)*.
- MILNES, A. R., LUDBROOK, N. H., LINDSAY, J. M., & COOPER, B. J. (1983) The succession of Cainozoic marine sediments on Kangaroo Island, South Australia. *Trans. R. Soc. S. Aust.* **107**, 1-35.
- PERON, F. & LESUEUR, C. A. (1816) *Voyage de découvertes aux terres australes*. 2 vols + Atlas (Paris).
- PERRY, G. (1811). "Conchology or the Natural History of Shells: containing a new arrangement of the genera and species, etc." Illust. London.
- QUOY, J. R. C. & GAIMARD, J. P. (1832-1835) In Dumont Duville, J. S. C. "*Voyage de découvertes de la Corvette l'Astrolabe ...*" Zoologie, **3**, (1833) Atlas 2 vols.

- REEVE, L. A. (1844) *Conchologia Iconica* 2. Triton.
- (1849) *Ibid.* 5. *Mesalia*.
- (1854) *Ibid.* 8. *Mesodesma*.
- (1855) *Ibid.* 8. *Patella*.
- (1856) *Ibid.* 9. *Siphonaria*.
- (1864) *Ibid.* 15. *Ancillaria*.
- SCHUMACHER, C. F. (1817) "Essai d'un nouveau Système des Habitations des Vers Testacés." (Copenhagen).
- SELBY, J. & LINDSAY, J. M. (1982) Engineering geology of the Adelaide City area, *Bull. geol. Surv. S. Aust.* 51.
- SINGLETON, F. A. (1941) Studies in Australian Tertiary Mollusca Part II. *Proc. R. Soc. Vict.* 53(2) n.s., 423-428, pl. 20.
- SOWERBY, G. B. (2) (1832) "The conchological illustrations". (London).
- (2) (1848) Descriptions of some new species of Cancellaria in the collection of Mr H. Cuming. *Proc. zool. Soc.* 136-137.
- SPRIGG, R. C. (1942) The geology of the Eden-Moana fault block, *Trans. R. Soc. S. Aust.* 66 (2), 185-214, 2 maps.
- SPRIGG, R. C. (1954) Geology of Kangaroo Island. In Sprigg, R. C., Campana, B. & King, D. KINGSCOTE map sheet, Geological Atlas of South Australia 4-mile series. (Geol. Surv. S. Aust.: Adelaide.)
- TATE, R. (1882) Diagnoses of new species of Miocene fossils from South Australia. *Ibid.* 5, 44-46.
- (1886) The lamellibranchs of the Older Tertiary of Australia Part 1. *Ibid.* 8, 96-158, pls 2-12.
- (1887a) A revision of the Recent lamellibranch and palliobranch Mollusca of South Australia. *Ibid.* 9, 76-111.
- (1887b) The lamellibranchs of the Older Tertiary of Australia Part 2. *Ibid.* 9, 142-200, pls 14-20.
- (1893) On some new species of Australian marine Gastropoda. *Ibid.* 17(1), 189-197.
- (1899) A revision of the Older Tertiary Mollusca of Australia, Part 1. *Ibid.* 23(2), 249-277.
- THOMSON, B. P. & HORWITZ, R. C. (1962) BARKER map sheet, *Geological Atlas of South Australia* 1:250 000 series. *Geol. Surv. S. Aust.*
- TWIDALE, C. R., DAILY, B. and FIRMAN, J. B. (1967) Eustatic and climatic history of the Adelaide area: A Discussion. *J. Geol.* 75(2), 237-242.
- WADE, A. (1915) The supposed oil-bearing areas of South Australia. *Bull. geol. Surv. S. Aust.* 4.
- WOOD, W. (1828) *Index Testaceologicus; or a catalogue of shells, British and foreign, arranged according to the Linnean system; etc.* Illust., London 2nd. ed. (W. Wood; London)
- WOODS, N. H. (1931) Pelecypoda from the Abattoirs Bore, including 12 new species. *Trans. R. Soc. S. Aust.* 55, 147-151, pls 7-8.

NOTES ON THE AUSTRALASIAN SPECIES OF CYMATIA FLOR S.L. (INSECTA, HETEROPTERA: CORIXIDAE)

BY IVOR LANSBURY

Summary

The validity of generically distinguishing the Australasian *Cymatia* from the rest of this primarily holartic genus is discussed. *Cnethocymatia* Jansson, 1982 proposed for *Cy. nigra* is relegated to subgeneric status within *Cymatia*. *Cymatia nigra* and the anomalous Asian species *Cy. Apparens* are both compared with the remainder of the known species.

NOTES ON THE AUSTRALASIAN SPECIES OF *CYMATIA* FLOR S.L. (INSECTA, HETEROPTERA: CORIXIDAE)

by IVOR LANSBURY*

Summary

LANSBURY, I. (1983) Notes on the Australasian species of *Cymatia* Flor s.l. (Insecta, Heteroptera: Corixidae). *Trans. R. Soc. S. Aust.* 107(1), 31-57, 31 May, 1983.

The validity of generically distinguishing the Australasian *Cymatia* from the rest of this primarily holarctic genus is discussed. *Cnethocymatia* Jansson, 1982 proposed for *Cy. nigra* is relegated to subgeneric status within *Cymatia*. *Cymatia nigra* and the anomalous Asian species *Cy. apparens* are both compared with the remainder of the known species.

KEY WORDS: Corixidae, *Cymatia nigra*, Australasia, *Cnethocymatia*, *Cymatia apparens*, holarctic.

Introduction

Five genera of Corixidae occur in Australia, *Diaprepocoris*, *Microneecta*, *Agriptocorixa*, *Sigara* and *Cymatia* (*Cnethocymatia*). Hungerford (1947) added *Cymatia*, the least known, when he described *Cy. nigra* based on a single female specimen from Prince of Wales Island. The type is in the Snow Entomological Collections, Lawrence, Kansas. The presence of the genus remained an enigma in Australia until 1979 when I collected a small series from pools in the Jullatten area of North Queensland. Subsequently a male specimen from Iron Range, Cape York Peninsula was located in the Dept. of Entomology, University of Queensland. Jansson (1982) studying *Cy. nigra* from New Guinea erected a new genus *Cnethocymatia* for Hungerford's species.

Generic concepts

Jansson's reinterpretation of *Cymatia* and its division draws attention to the problems of subfamily/tribal classification in the Corixidae (Corixinae). *Cymatia* has at various times been accorded subfamily or tribal status. Walton in Hutchinson (1940) placed the genus in the Corixinae—*Cymatiini* trib. nov. Walton (1943) expanded his comments on the classification of the Corixidae but these observations were criticised by Hungerford (1948). China (1943) placed *Cymatia* in the *Cymatiinae* without comment. Hungerford's (1948) review of the Corixidae increased the number of subfamilies to six describing the *Cymatiinae* as a new subfamily without reference to China's (1943) usage. Both authors included

only one genus, *Cymatia* (type species *coleoptrata* (F.)).

Leston (1955) summarised and tabulated the previous classifications of the Corixinae and relegated *Cymatiinae* to tribal status. Popov (1971) gave cogent reasons for including *Cymatia* in the Corixinae in a classification which included fossil forms. Jansson (1982) follows Hungerford *et al* in treating *Cymatia* and *Cnethocymatia* as belonging to a separate subfamily. Jacewski (1964) reviewed *Cymatia* and regarded the genus as the most archaic (plesiomorphic) of all the Corixinae. Features to which Jacewski drew attention included: short claws of middle legs, absence of "pala" pegs, no strigil and the lack of pronounced asymmetry of the male abdomen. Jacewski arranged the species in two groups. With the exception of *Cy. nigra* and *Cy. apparens* (Distant) the remaining species are all remarkably uniform in structural features.

Definition of *Cymatia* Flor 1860 s.l.

Rostrum smooth without transverse sulcations. Front tarsus (pala) elongate, cylindrical with negligible palms. Male pala with a broad thickened claw (Fig. 10), female much like the male but with spine in place of thickened claw.

In most of the Corixinae there are considerable differences between the male and female palae, with those of the male having one or more rows of stout pegs on the face of the pala (Lansbury, 1970). Features cited by Hungerford (1948: p. 99) which call for comment include the presence of a nodal furrow in *Cymatia*. He states "the median vein appearing to curve abruptly downwards to

* Hupe Entomological Collections, University Museum, Oxford, U.K.

costal margin without making contact with cubitus. The location and direction of this curved portion of media suggests a nodal furrow. There is however, no indication of a cleavage plane which is characteristic of a nodal furrow". Partial maceration of a hemelytron (Fig. 4) seems to show a vestigial nodal furrow, but it is almost certainly an artifact.

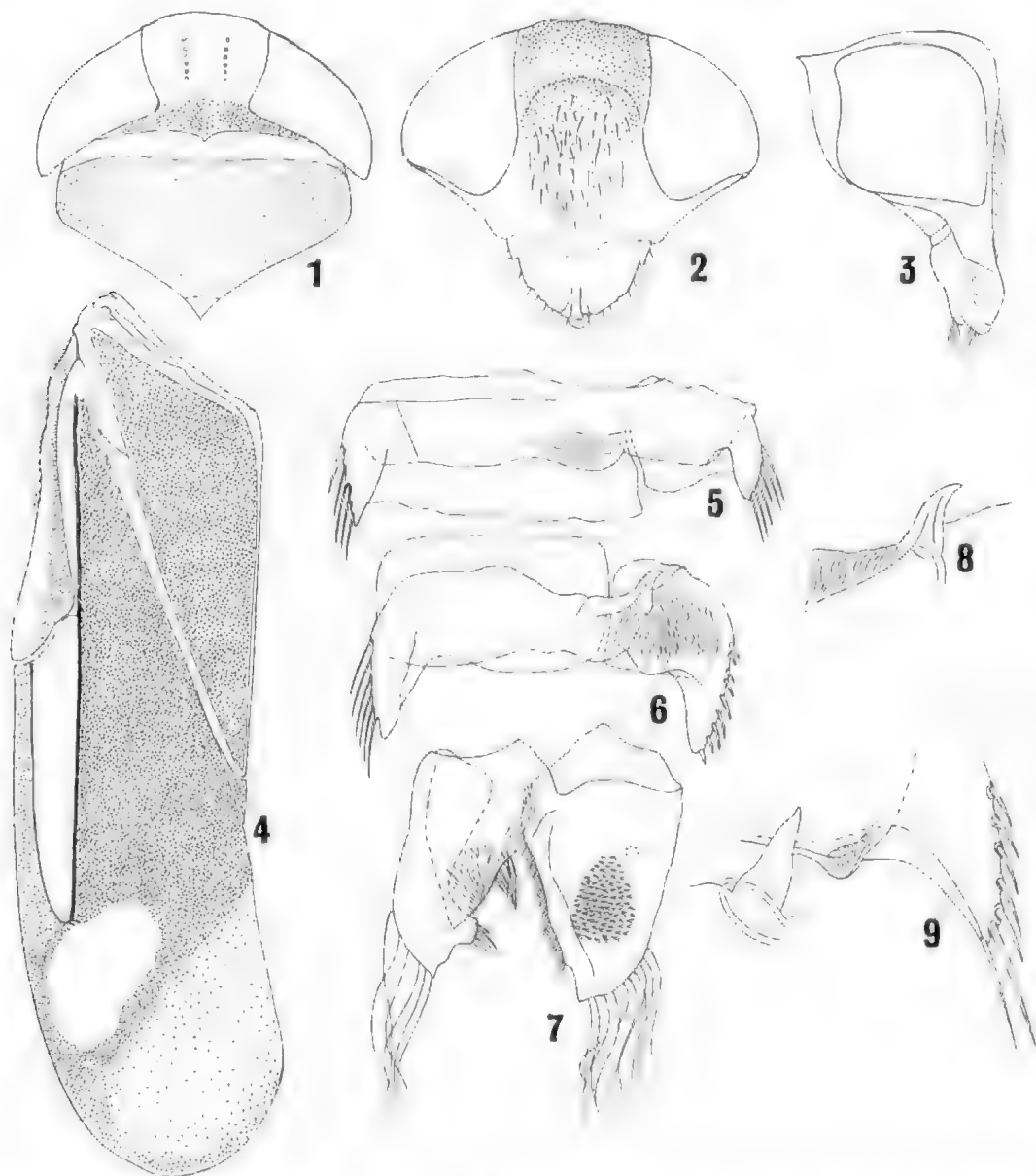
Cymatia species and their distribution

Cymatia coleoprata (F.), widely distributed euro-asian element including North Africa.

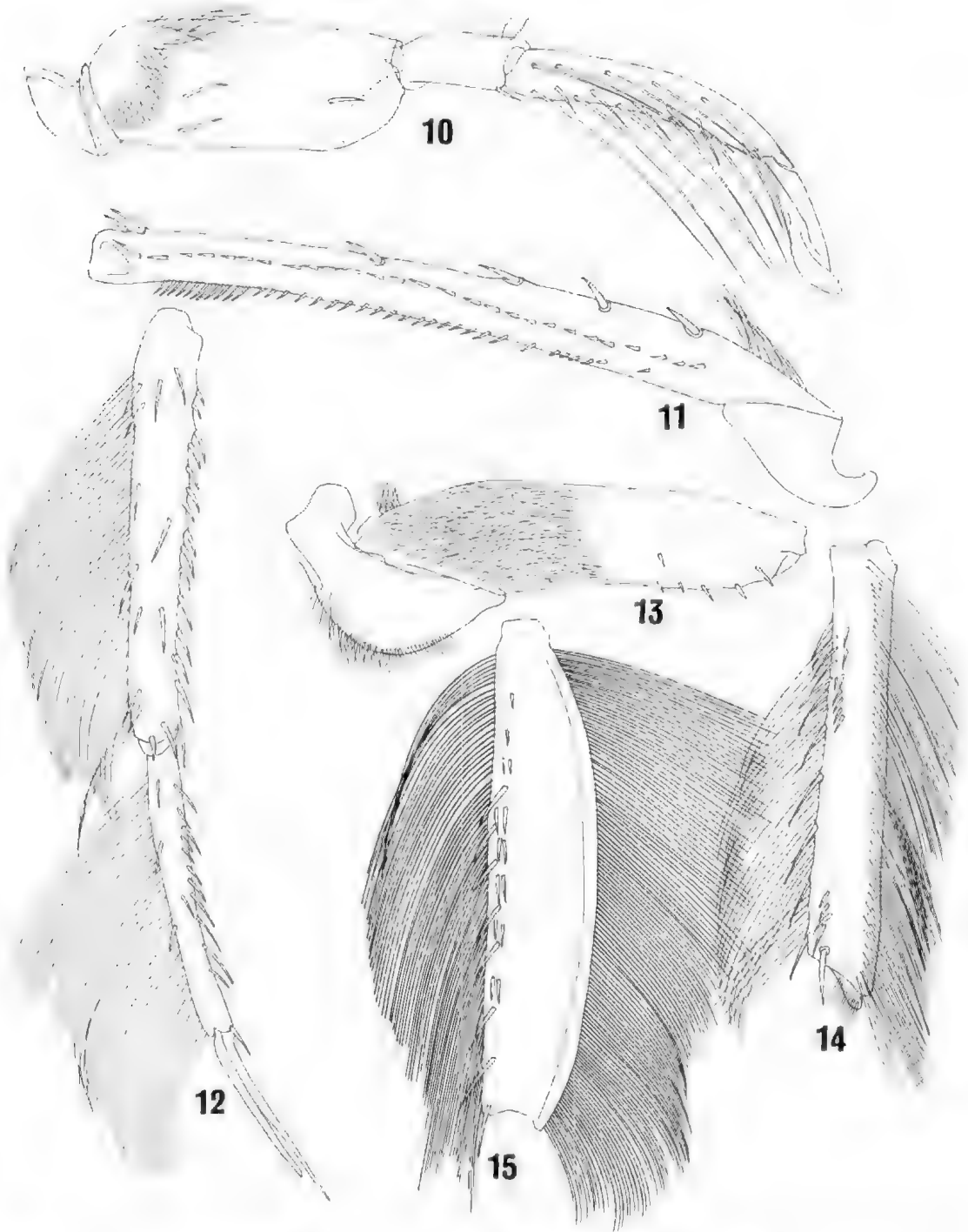
Cy. bondsdorffi (C. Sahlberg), Europe and part of Western Asia.

Cy. rogenhoferi (Fieber), temperate Europe through to Hindu Kush and North Africa.

Cy. apparens (Distant), temperate China, Tibet, Kashmir, India and Japan.



Figs 1-9. *Cymatia nigra*, male. 1, dorsal view of head and pronotum; 2, frontal view of head; 3, lateral view of head; 4, hemelytra; 5, 6th tergite; 6, 7th tergite; 7, 8th tergite; 8 & 9, detail of 6th and 7th tergites.



Figs 10-15. *Cymatitia nigra*, male. 10, front leg; 11, middle femur; 12, middle tibia, tarsi and claws; 13, hind femur; 14, hind tibia; 15, 1st hind tarsus.

Cy. americanu Hussey, Alaska, Canada and the continental U.S.A

Cy. nigra Hungerford, Prince of Wales Island, North Queensland, Papua New Guinea and N.W. Irian.

(from Jaczewski and others).

Cymatla (*Cnethocymatla*) *nigra* Hungerford
FIGS 1-23

Cymatla nigra Hungerford, 1974, *J. Kansas Entomol. Soc.* 20, 154-157.

Cnethocymatla nigra: Jansson, 1982, *Pacific Insects* 24, 95-98.

Description: (based on male, 5 mm long (alcohol specimen)).

Colour: head orange yellow with posterior margin between and behind eyes dark brown to black (Figs 1 & 2). Pronotum and hemelytra uniformly shining dark chocolate brown other than distal outer margin of corium which has bright yellow spot, left membrane pale yellow (Fig. 4). Right membrane same colour as elytra. Embolium, sternum and legs dark brown.

Structurally *Cy. nigra* resembles a generalised *Cymatla*, a number of characters set *Cy. nigra* apart from the rest of the genus: non-carinate pronotum (Fig. 1); more or less unicolorous pronotum and elytra (Fig. 4); sclerotised ridge on the 6th tergite (Figs 5 & 9); prominent projection on the 7th tergite (Figs 6, 8 & 9); group of stout setae on 8th lateral lobe (Fig. 7); left lobe of 8th sternite infolded (Fig. 7).

Male fovea not prominent and only moderately pilose (Figs 2 & 3). Tergites 6-8 each bear specialisations not found on other species (see above). Front leg typical (Fig. 10). Middle legs longer than hind legs and have conspicuous but not dense fringe hairs (Figs 11 & 12), the function of which is not clear, possibly grooming and cleaning. Hind tibia bear several rows of long hairs which probably have a similar function (Fig. 14). Tarsi have long dense fringes of swimming hairs (Figs 15 & 16), (longer and denser than shown in the figures). Metaxyphus and scent gland osteoles (Fig. 17). Lateral lobe of prothorax (pronotum) (Fig. 18). Antennae four segmented (Fig. 23).

Male genitalia: genital capsule asymmetrical, slightly deeper dorso-ventrally than long (Fig. 19). Rim of "dorsal" opening heavily sclerotised. Posterior diverticulum continuous with and extending into capsule ventrally where attached to sclerotised plates arising



Figs 16-23. *Cymatla nigra*, male. 16, 2nd hind tarsus; 17, osteole and metaxyphus; 18, lateral lobe of prothorax; 19, genital capsule; 20, aedeagus; 21, left paramere; 22, right paramere; 23, antennae.

from "floor" of capsule. Diverticulum not symmetrical with capsule, more broadly attached to right margin and narrowly so to left margin of capsule. Left paramere (Fig. 21) large, lateral margins infolded; together with curved lateral margins of diverticulum. Strongly sclerotised "half-moon" shaped support provided for aedeagus (Fig. 20). Bias to right of diverticulum allows sufficient space for left paramere. At visible base of left paramere post-capsule, large curved projection overlying aedeagus. Right paramere small and membranous, attached to basal plate and inner wall of capsule (Figs 20 & 22). When right paramere in position with diverticulum and left paramere, forms a "T" junction with projection on latter.

The asymmetry of the genital capsule of *Cy. nigra* is more pronounced than that of *Cy. apparens* (Fig. 24); the capsules of *Cy. honsdorffi* and *Cy. coleoprata* are much less sclerotised than those of *Cy. nigra* and *Cy. apparens*. Hungerford (1948) figures the capsule of *Cy. americanu* without comment.

Distribution: Queensland, Julatten, 20.v.1979, water-lily lagoon, permanent pool with plenty of macrophytes, water clear, substrate silty; 1 male 2 female and 1 immature *Cy. nigra*. In the same habitat, *Sigara tadeuzi*, *Agraptocorixa eurynome*, *Enithares loria*, *Anisops*

tahitiensis, *Limnogonus fossarum skuei* and *Diplonychus eques*.

Queensland, Julatten, 20.v.1979, small pool shaded by bamboo, bottom covered with bamboo leaves; 1 male *Cy. nigra*. In the same habitat, *Agratocorixa halei*, *Anisops elstoni* and *Ranatra diminuta*. Queensland, Iron Ranges, Cape York Peninsula, 16-623.xi.1965, G. Monteith; 1 male (University of Queensland).

Jansson (1982) records *Cy. nigra* from various localities in New Guinea, most of the material having been taken at light.

Within Australia *Cy. nigra* appears to be limited to Northern Queensland. Present data give few clues of habitat preferred other than the immature found at Julatten. Other pools in the area i.e. farm dams with and without vegetation and rain forest creeks had fairly diverse faunas but *Cy. nigra* was not found.

Discussion

Jansson (1982) concluded after studying *Cy. nigra* from New Guinea that Hungerford (1947) had been too conservative in placing *Cy. nigra* in *Cymatia* and erected the genus *Cnethocymatia* for *Cy. nigra*. In a simple key Jansson separated *Cnethocymatia* from *Cymatia* because the pronotum is not carinate and the male has a "finger-like" projection on the 7th tergite. Jansson's broader generic description includes face reduced, rostrum without transverse sulcations, palae elongate cylindrical etc. . . . All these characters apply equally well to *Cymatia*, only the smooth pronotum and projection on the male 7th tergite distinguish *Cy. nigra* from the rest of the genus. Placing *Cy. nigra* in a separate genus is an attractive proposition as it removes the

Australasian species from what is otherwise an entirely holarctic genus. Jansson (1982) states that the finger-like projection on the 7th tergite is analogous with the strigil of many Corixidae (Corixinae). He contends it cannot be homologous with the strigil as it is on the 7th segment, not the 6th which is where the strigil invariably is, if present. The two males of *Cy. nigra* I examined have a thickened sclerotised area on the 6th tergite where the strigil would be if it were present (Figs 5 & 9). The finger-like projection may act as Jansson suggests as a method of attaching male to female during pairing, but the function of the sclerotised ridge on the 6th segment is unknown. As the finger-like projection could overlap the sclerotised ridge, the latter may also have an epigamic function.

Cymatia nigra differs from the other species in a variety of male primary and secondary sexual characters and some colour features (Table 1); in females the only obvious distinction is the smooth pronotum and colouration. Because of the necessity to use tribal/family characters to define *Cnethocymatia*, it is relegated subgeneric status within *Cymatia* (type species *nigra*).

Cymatia apparens (Distant)

FIGS 24-30

Corixa apparens Distant, 1910, Fauna British India, Heteroptera Appendix Vol. 5:343 fig. 204.

Cymatia apparens is not as well known as the other holarctic species. Jacewski (1928) showed that *Cy. apparens* belonged to *Cymatia* not *Corixa*. Besides Calcutta (type locality) he mentioned its presence in Chikkaballapura, S. India and Schantung Province, Yenchowfu,

TABLE 1. Comparison of *Cymatia nigra* with other species of *Cymatia*.

	Pronotum variably carinate	Pronotum unicolorous	Clavus/ corium variously striped light-dark brown	Vertex between eyes strongly protuberant	Right posterior margin of ♂ 6th tergite sclerotised (Fig. 9)	Finger-like projection on ♂ 7th tergite (Figs 8 & 9)	Left lobe of ♂ 8th sternite infolded (Fig. 7)	Right lobe of ♂ 8th tergite spinose (Fig. 7)
<i>Cymatia nigra</i>	—	+	—	—	+	+	+	+
<i>Cymatia apparens</i>	+	—	+	—	—	—	—	—
<i>Cymatia coleoptera</i>	+	—	+	+	—	—	—	—
<i>Cymatia rogenhoferi</i>	+	—	+	+	—	—	—	—
<i>Cymatia bondorffi</i>	+	—	+	+	—	—	—	—
<i>Cymatia americana</i>	+	+	+	+	—	—	—	—

China, Lundblad (1933) gave a short resumé of previous accounts and recorded *Cy. apparens* from Peking. Hungerford (1947 & 1948) included *Cy. apparens* in keys to *Cymatia* species. Although *Cy. apparens* is the nearest geographically to *Cy. nigra*, it differs not only from the Australasian species but from the rest of the genus.

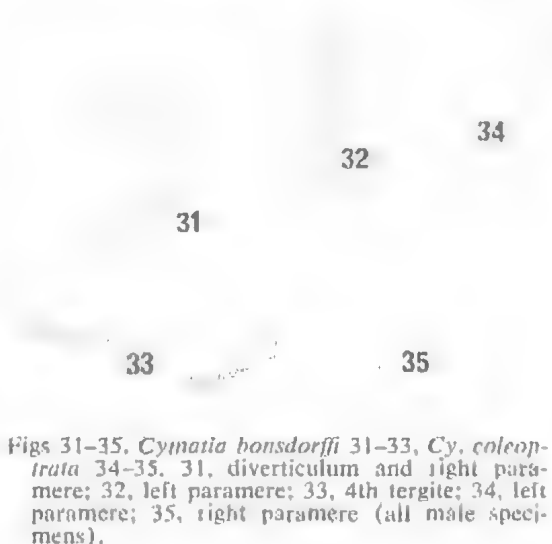
The distribution of *Cy. apparens* suggests that it is a 'plastic' species occurring as it does in the tropics (Calcutta) and Tibet-Japan, being tolerant of extreme conditions or possibly more than one species is included under the name.

Discussion

Cymatia s.l. is a homogenous group, although not applicable to the Australian Corixinae genera, *Sigara*, *Agraptocorixia* and *Cymatia*; the limits of many Corixinae genera are rather diffuse, few being as well defined as *Cymatia*. Excluding *Cy. nigra*, *Cy. apparens* is the most atypical tending to resemble a generalised *Sigara*. Of the other *Cymatia* species, *Cy. bonndorffi* has a prominent lobe on the 4th tergite (Fig. 33). The general structure of the male genitalia of *Cy. bonndorffi* and *Cy. coleoptrata* (Figs 31-33 & 34-35) respectively are typical *Cymatia*. All the males have similar parameres, the left being large and spinose on the outer margin, variously blunt or acuminate apically. The left paramere is a little more variable; that of *Cy. bonndorffi* is fairly large, likewise that of *Cy. americana* (see Hungerford, 1948). Those of *Cy. nigra*, *Cy. apparens* and *Cy. coleoptrata* (Figs 22, 24 & 35) respectively are small and membranous. According to Hungerford (1947) *Cy. rogenhoferi* does not have a right paramere; Posson (1957) states that it has a vestigial right paramere. In most Corixinae genera the left and right parameres are prominent sclerotised structures.

Figs 24-30. *Cymatia apparens*, male. 24, genital capsule; 25, oblique view of diverticulum and right paramere; 26, left paramere; 27, aedeagus; 28-30, 6th-8th tergites.

The fovea in both sexes is practically obsolete and the pronotum and elytra are *Sigara*-like being arranged in irregular transverse and longitudinal light and dark bands respectively. Distant (1910) described the pronotum as unicolorous pitchy brown overlooking the faint transverse bands on the pronotum. Tergites 6-8 (Figs 28-30) do not have any of the structures found on *Cy. nigra*. The genital capsule (Fig. 24) is like that of *Cy. nigra*. The diverticulum (Figs 24 & 25) is more robust with parameres (Figs 25 & 26) similar to *Cy. nigra*. The left paramere is figured showing inner aspect and curved projection near its base (Fig. 26) and the right paramere shown attached to the capsule. The 8th abdominal segment has the more usual over-lap on both surfaces, the left lobe not being infolded (Fig. 30).



Figs 31-35. *Cymatia bonndorffi* 31-33, *Cy. coleoptrata* 34-35. 31, diverticulum and right paramere; 32, left paramere; 33, 4th tergite; 34, left paramere; 35, right paramere (all male specimens).

Unlike most of the Corixinae, it is known that some at least of the *Cymatia* species are predacious rather than filter feeders. The elongate cylindrical front legs of both sexes are used to grasp prey. With the exception of *Cy. nigra* and *Cy. apparens* the remaining species have very pronounced broad rounded grooves on the front of the head (fovea). The prey is held in the groove. The general feeding behaviour of *Cy. bouisdorffi* and *Cy. coleoptrata* has been observed by me. Both species are found most abundantly in water 1 m or more deep with dense stands of submerged macrophytes or rocks presenting vertical faces over-looking clear water. The *Cymatia* cling to

the vertical surfaces and actively seek prey which includes other corixids, water fleas, chironomids and mayfly larvae.

Acknowledgments

I wish to thank the Leverhulme Trust, London and the Australian Biological Resource Study for their generous assistance, Dr D. F. Waterhouse, Mr Murray-Upton and Mr T. Weir (CSIRO, Canberra) for their invaluable help whilst in Australia. Mr Walford-Higgins helped me greatly in the Molloy-Jullaten region and Dr T. E. Woodward and Dr G. Montieth were of great help during my stay in Brisbane.

References

- CHINA, W. E. (1943) The generic names of the British Hemiptera-Heteroptera, with a check list of British species; in *The Generic names of British Insects*. *R. ent. Soc. Lond.* **1**(8), 211-342.
- HUNGERTORD, H. B. (1947) A new species of *Cymatia* from Australia. *J. Kansas Entomol. Soc.* **20**(4), 154-7.
- (1948) The Corixidae of the Western Hemisphere. *Univ. Kansas Sci. Bull.* **32**, 1-827.
- HUTCHINSON, G. E. (1940) A revision of the Corixidae of India and adjacent regions. *Trans. Connecticut Acad. Art Sci.* **33**, 339-476.
- JACZEWSKI, T. (1928) Über drei Arten aquatiler Heteropteren aus China. *Ann. Mus. Zool. Polon* **8**(4), 107-14.
- (1964) On *Cymatia laxartensis* Kiritschenko, with some general notes on the genus *Cymatia* Flor. (Heteroptera, Corixidae). *Bull. Acad. pol. Sci. Cl. II Ser. Sci.* **11**, 545-8.
- JANSSON, A. (1982) Notes on some Corixidae (Heteroptera) from New Guinea and New Caledonia. *Pacific Insects* **24**, 95-103.
- LANSBURY, I. (1970) Revision of the Australian *Sigara* (Heteroptera-Corixidae). *J. Nat. Hist.* **4**, 39-54.
- LARSEN, O. (1938) Untersuchungen über den geschlechtsapparat der aquatilen wanzen. *Opusc. Ent. Suppl.* **1**, 1-388.
- LESTON, D. (1955) Taxonomy of the British Corixidae (Hem.). *Ent. mon. Mag.* **91**, 57-9.
- LUNDBLAD, O. (1933) Some new or little known Rhynchota from China. *Ann. Mag. nat. Hist.* (10) **12**, 449-64.
- POISSON, R. (1957) Hémiptères Hétéroptères-aquatiques. *Fauna de France* **61**, 1-263.
- POPOV, Y. A. (1971) Historical development of Hemiptera Infraorder Nepomorpha (Heteroptera). *Trudy Palaeontological Institute, Acad. Sci. USSR* **129**, 1-228 [in Russian; informal translation in English by H. Vaitatis].

NEW RECORDS (POSSIBLY INTRODUCTIONS) OF STRIARIA, STICTYOSIPHON AND ANTHROCLADIA (PHAEOPHYTA) FOR SOUTHERN AUSTRALIA

BY S. SKINNNER & H. B. S. WOMERSLEY

Summary

Three species of Phaeophyta, *Striaria attenuata* and *Stictyosiphon soriferus* in the family Striaceae of the Dictyosiphonales and *Anthrocladia villosa* of the Demarestiales, are newly recorded for southern Australia. Description and illustrations are given of the Australian material, which agrees well with these species.

NEW RECORDS (POSSIBLY INTRODUCTIONS) OF *STRIARIA*, *STICTYOSIPHON* AND *ARTHROCLADIA* (PHAEOPHYTA) FOR SOUTHERN AUSTRALIA

by S. SKINNER & H. B. S. WOMERSLEY*

Summary

SKINNER, S. & WOMERSLEY, H. B. S. (1983) New records (possibly introductions) of *Striaria*, *Stictyosiphon* and *Arthrocladia* (Phaeophyta) for southern Australia, *Trans. R. Soc. S. Aust.* **107**(1), 59-68, 31 May, 1983.

Three species of Phaeophyta, *Striaria attenuata* and *Stictyosiphon soriferus* in the family Striariaceae of the Dictyosiphonales and *Arthrocladia villosa* of the Desmarestiales, are newly recorded for southern Australia. Descriptions and illustrations are given of the Australian material, which agrees well with these species.

All three species are well known as European and British marine algae, occurring in the Mediterranean and eastern North America. They occur often in harbours and it appears probable that they have been introduced to southern Australian waters, possibly by shipping, since the known Australian localities are near harbours.

KEY WORDS: *Striaria attenuata*; *Stictyosiphon soriferus*; *Arthrocladia villosa*; Phaeophyta; southern Australia.

Introduction

Three species of brown algae (Phaeophyta) have been collected recently on southern Australian coasts, in most cases associated with harbours. There are no records in the literature of their presence previously, and no earlier specimens have been located in Australian herbaria.

There are only a few species of Dictyosiphonales (excluding the Scytosiphonales) known in southern Australia. The family Punctariaceae is represented by *Punctaria latifolia* Greville (Clayton & Ducker 1970) and by *Adenocystis utricularis* (Bory) Skottsberg in Tasmania and *Asperococcus bullus* Lamouroux more generally in sheltered waters along the coast (Womersley 1967). The family Giraudyaceae is represented by *Giraudya sphacelarioides* Derbes & Solier and by two further taxa to be described.

The family Striariaceae is not previously known on southern Australian coasts since the dubious genus *Xanthosiphonia* J. Agardh (with *X. watsii* J. Agardh from Victoria) was rejected by Womersley (1967, p. 242), and omitting the dubious records of the little known *Cladothele decussata* Hooker & Harvey from Tasmania (Womersley 1967, p. 247). The presence of the two genera, *Striaria* and *Stictyosiphon*, now establishes this family in southern Australian waters.

The only member of the Desmarestiales previously recorded for southern Australia is *Desmarestia ligulata* (Lightfoot) Lamouroux, which occurs very occasionally on the south-eastern coasts. The discovery of *Arthrocladia villosa*, at Port Stanvac in South Australia, constitutes a second record for a genus of this order.

Order DICTYOSIPHONALES

Family STRIARIACEAE

Thallus (sporophyte) slender, usually much branched, each branch with a uniseriate terminal row of cells ending in a hair, with cells below the meristem first dividing once transversely and later longitudinally to form a parenchymatous axis which differentiates into a pigmented cortex one cell thick and internal medulla a few cells across; lateral hairs also present on the branches.

Generations heteromorphic; sporophyte with unilocular (meio) sporangia in superficial sori and plurilocular (mito) sporangia differentiated from cortical cells; gametophyte filamentous, bearing plurilocular gametangia.

The Striariaceae contains two well known genera, *Striaria* and *Stictyosiphon*, as well as *Isthmoploea* Kjellman, *Hummia* Fiore (1975, 1977) and probably *Cladothele* Hooker & Harvey (Skottsberg 1921, p. 36). The latter genus was ascribed to Tasmania by De Toni, referring to Harvey, but this appears to be incorrect (Womersley 1967, p. 247).

*Department of Botany, University of Adelaide, South Australia 5000.

Key to the Taxa of the Striariaceae in southern Australia

1. Cortication of the axes commencing about 20 cells below the apex; lateral axes basally attenuate; medulla of numerous similar sized cells in two layers immediately below cortex and surrounding a hollow axis; unilocular sporangia in discrete sori superficial to cortex, with unicellular paraphyses.

..... *Striaria attenuata*

1. Terminal uniseriate moniform filament 1-2 cm long with cortication of axis commencing well below apex; lateral axes not constricted at base; medulla of four large cardinal cells in the centre and peripheral cells below cortex, giving a solid axis; plurilocular sporangia scattered, formed in groups of four to eight within each cortical cell, without paraphyses

..... *Stictyosiphon sortifera*

STRIARIA Greville 1828: 44

Rosenvinge & Lund 1947: 59.

Thallus polystichous becoming hollow, much branched, each branch with a terminal hair subtended by a short uniseriate filament and transverse tiers of cortical cells below, surrounding a medulla of one to two layers of larger clear cells. Unilocular sporangia superficial in sori in discontinuous bands around axes, with paraphyses. Plurilocular sporangia unknown on macrothallus, but reported on microthallus (Caram 1965).

Type and only species, *S. attenuata* Greville.

Striaria attenuata Greville 1828: 44; 1830: 55, pl. ix. Kornmann & Sahling 1973: 14, Figs 3B, 7-9. Rosenvinge & Lund 1947: 59.

Thallus (Fig. 1A) yellow brown to medium brown (banded in appearance), 10-15(-30) cm tall, polystichous, becoming hollow, extensively branched more or less in one plane, branches terete above, becoming compressed below, basally attenuate, terminating in a hair (Fig. 2D) and with a short, uniseriate filamentous region; holdfast small, discoid with slight rhizoidal development.

Uniseriate apices 10-15(-20) cells long, 12-17 μ m in diameter, cells L/B 1/3-1/2 (Fig. 2D). Cortex in tiers (Fig. 2E,F), sometimes less clear in older parts of branches, single layered, with (10-)20-50(-70) cells per tier, cells rectangular and slightly domed, 15-22 μ m broad, isodiametric and about 12

μ m deep, phaeoplasts discoid and numerous. Medulla (Fig. 2C) one or two layered, cells large and clear with smaller cells outside larger, essentially in tiers. Hairs (Fig. 2D) terminal and lateral, solitary but in open whorls around the axis, each with a basal cell narrower than subtending cortical cells, a short (2-4 celled) meristem, and non-pigmented cylindrical cells above, 8-10 μ m in diameter, L/B 3-15 (Fig. 2D). Similar hairs present in sori of unilocular sporangia.

Reproduction. Unilocular sporangia (Fig. 2A, B) ovoid to pyriform, about 45 μ m at greatest diameter, 45-55 μ m long, opening by rupture, occurring in superficial circular sori with ovoid paraphyses of similar dimensions to sporangia, with prominent physodes, and several hairs; sori in discontinuous bands around axes; further periclinal divisions occur in cortical cells beneath sori, with each smaller cortical cell subtending a sporangium or paraphysis. Plurilocular sporangia unknown on macrothalli.

Type locality: Isle of Bute, Scotland (Carmichael).

Type: C.

Distribution: North Atlantic (Europe and U.S.A.) and Mediterranean; New Zealand. In Australia from West Lakes (Port Adelaide), S. Aust., and Southport, Tasmania.

Specimens examined: Eastern loop, West Lakes, Port Adelaide, 1 m deep (Steffensen, 20.x.1978; ADU, A49759). Southport, Tasmania, on jetty piles (Cribb, 77.10.23.x.1950; ADU, A16249). New Zealand: Stewart Island, (Parsons, 1.xii.1971; CHR, 219372).

This distinctive species is known from only one collection in South Australia and the older Cribb collection from Tasmania. Further occurrences may well be expected.

The life history of French and Danish material (Caram 1965, 1966; Caram & Nygren 1970; Nygren 1975) has a direct asexual phase and, under certain temperature and daylength conditions, an alternation of gametophyte (microthalli) and sporophyte (macrothallial) generations.

STICTYOSIPHON Kuetzing 1843: 301

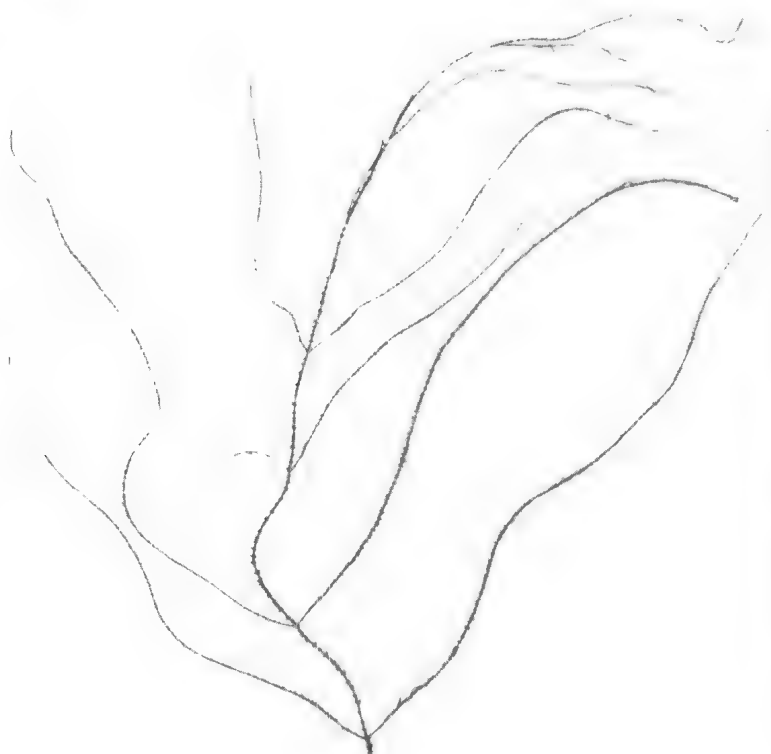
Naylor 1958: 7

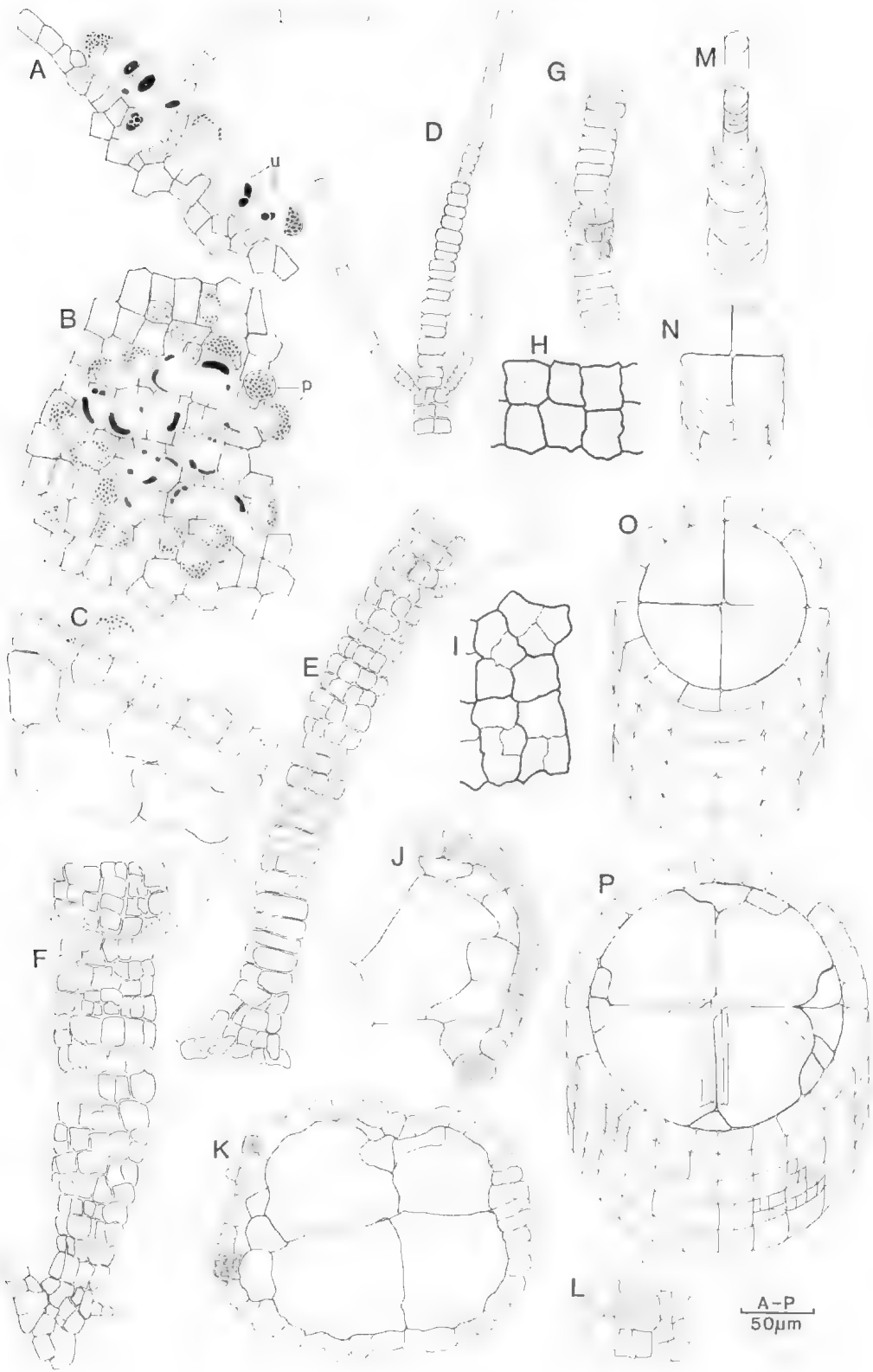
Thallus polystichous, usually solid (becoming hollow in *S. adriaticus*), branched, with a

Fig. 1. A, *Striaria attenuata* Grev., West Lakes, Port Adelaide, S. Aust. (Steffensen, 20.x.1978; ADU, A49759). B, *Stictyosiphon sortifera* (Reim.) Rosenvinge, Kirk Point, Port Phillip, Vic. (Womersley, 30.viii.1981; ADU, A53240). C, *Arthrocladia villosa* (Huds.) Duby, Port Stanvac, S. Aust. (Clarke, 28.xii.1981; ADU, A52837). All to same scale, large divisions in centimetres.



C





terminal hair to the branches subtended by a long uniseriate filament with corticated tiers at origin of branches, and transverse tiers of cortical cells well below apices, surrounding a medulla of four central cardinal cells and smaller subcortical cells. Unilocular sporangia formed in individual cortical cells. Plurilocular sporangia developed from cells of the uniseriate filaments, or in groups of one to eight in cortical cells.

Type species: *S. adriaticus* Kuetzing.

A genus of four or five species, in the North Atlantic, Mediterranean, and North Pacific.

Stictyosiphon soriferus (Reinke) Rosenvinge 1935: 9, figs 9–19. Feldmann 1937: 156, fig. 59. Hamel 1937: 205. Naylor 1958: 16, figs 1C, D, 2D, E, G, 3C. Rosenvinge & Lund 1947: 59. South & Hooper 1976: 24, figs 3, 4. *Kjellmania sorifera* Reinke 1889: 59; 1889, pl. 3.

Thallus (Fig. 1B) light to medium brown, 10–15(–35) cm high, polystichous, much branched, terete, with terminal hairs and many-celled uniseriate ends to branches; holdfast of descending multicellular rhizoids arising from cortical cells at and near the base of the main axis. The whole outer thallus may have a mucilaginous coat.

Uniseriate filaments with cells (10–)15–30 μm in diameter, L/B 1–2/3 (Fig. 2G, M). Erect axes solid and essentially two layered, with a single layered cortex and a medulla of hyaline cells with four (3–5) cardinal cells (= axial cells in Rosenvinge 1935 and Naylor 1958) with subsidiary subcortical cells cut off at their periphery, starting at the junctions of the walls of cardinal cells and forming a partial second medullary layer in mature axes (Fig. 2 K, O, P); cells of both cortex and medulla in transverse tiers. Cortex of rectangular cells in surface view, slightly domed, (12–)15–30(–35) μm broad, 12–25 μm deep;

L/B 2/3–1 (Fig. 2 H, I). phacoplasts numerous, round to ovoid, without pyrenoids. Medulla with cardinal cells 120–210 μm in diameter and 120–150 μm long (Fig. 2K). Hairs (Fig. 2 G) with a basal cell, a short intercalary meristem of 4–6 cells and cylindrical cells above without phacoplasts, 5.5–8 (–10) μm in diameter, L/B 3–12.

Reproduction. Unilocular sporangia modified from cortical cells (recorded for Danish material only by Rosenvinge 1935, p. 14, fig. 14). Plurilocular sporangia of two kinds: intercalary plurilocular sporangia in uniseriate filaments recorded in European material (Rosenvinge 1935, p. 13, fig. 11A), but not seen in southern Australian material. Cortical plurilocular sporangia formed by one or a small group of mature cortical cells (Fig. 2J, K, L) in patches. Mother cell cutting off a basal stalk cell or not, then dividing into four to eight multiseriate plurilocular sporangia, 15–35 μm tall, loculi 2–3 μm in diameter, cross walls persistent.

Type locality: West Baltic Sea.

Lectotype: in KIEL (Naylor 1958).

Distribution: North Atlantic and Mediterranean. In southern Australia, from Albany, W. Aust. to Port Phillip, Vic., in harbours.

Specimens examined: Princess Royal Harbour, Albany, W. Aust.; upper sublittoral (Womersley, 21.viii.1979; ADU, A51388); Billy Lights Point, Port Lincoln, S. Aust., 12 m deep on *Pinna* (Shepherd, 23.viii.1975; ADU, A46532); Geelong, Vic. (Clayton, 4.ix.1970; MELU, 21035); Swan Bay, Queenscliff, Vic. (Clayton, 18.ix.1969; MELU, 21054); Gellibrand Light, Port Phillip Bay, Vic. (Lewis, 20.x.1976; MELU, L0805); Kirk Point, Port Phillip, Vic., uppermost sublittoral (Womersley, 30.vii.1981; ADU, A53230). *European specimens examined:* Roscoff, France, laboratory aquarium, (Feldmann 8663, 4.v.1953; ADU, A24276) *Stictyosiphon adriaticus* Kuetz., Banyuls-sur-mer, France, 40 m deep (Feldmann 7654, 25.viii.1950; ADU, A24197).

Fig. 2. A–F. *Striaria attenuata* Grv. (ADU, A49759). A. Margin of mature thallus, with sorus of unilocular sporangia. B. Sorus of unilocular sporangia and surrounding paraphyses, viewed from above. C. Transverse section of part of mature thallus, with paraphysis, single layered cortex and double layered medulla. D, E. Tip and base of very young lateral. F. Older lateral showing attenuation of base. G–L. *Stictyosiphon soriferus* (Reinke) Rosenvinge (ADU, A53230). G. Part of uniseriate filament showing initiation of laterals. H. Surface view of young corticated axis, showing primary and secondary division of cells. I. Surface view of part of mature corticated axis, showing primary, secondary and tertiary division of cells. J. Transverse section of mature axis (part), with cortical cells transformed into plurilocular sporangia at various stages of maturity. K. Transverse section of mature axis. L. Surface view of cortical cell transformed into several plurilocular sporangia. M–P. Isodiametric reconstruction of *Stictyosiphon soriferus*. M. Terminal hair and uniseriate filament. N. Primary division of cells below uniseriate filament. O. Young axis, showing 4 cardinal cells and peripheral cortex. P. Mature axis p = paraphyses; u = unilocular sporangium.

TABLE 1. Comparison of *Stictyosiphon adriaticus* Kützmg, *S. soriferus* (Rke) Rosenvinge and southern Australian material, based on Naylor (1958).

<i>S. adriaticus</i>	<i>S. soriferus</i>	southern Australian collections
medullary cells rounded, and irregularly arranged	cardinal cells large, rounded and uniform in size	cardinal cells large, rounded, regularly arranged but not uniform in size
axis may soon become hollow	axis solid	axis solid
branching whorled	branching alternate	branching alternate, occasionally opposite, initially whorled
internal walls of plurilocular sporangia disappear before release	internal walls of plurilocular sporangia retained	internal walls of plurilocular sporangia retained
hairs always present	hairs generally lacking or sparse	hairs always present, frequency variable
small elongate phaeoplasts (Feldmann 1937)	rounded phaeoplasts (Feldmann (1937)	phaeoplasts round to elongate in same specimen
cortical cells to 50 μ m in diameter (Feldmann 1937)	cortical cells 20–30 μ m in diameter (Feldmann 1937)	cortical cells 15–35 μ m in diameter

Branching of the thallus takes place in the uniseriate region of the axis (Fig. 2G). An isolated node of one to three tiers each of two to four cells is formed, and from each tier arises one, two or occasionally three hair initials, each from a separate cell; one, or sometimes two, of these hair initials gains dominance and will grow into a new uniseriate axis, while the other hair initials will remain as solitary lateral hairs. Solitary hairs may also be formed following a single longitudinal division of a uniseriate cell, giving a smaller initial cell, lateral to the main uniseriate cell.

Complete cortication and medulla formation occurs in the axis behind the region of branch initials. After the initial division into four cells the tiers of cortical (photosynthetic) cells rapidly increase in number to eventually give tiers of thirty to forty cells. The wall of the original cortical cell (the middle lamella of which takes up aniline blue strongly) is retained and two or more internal divisions of the cortical cells give the rectangular patch pattern seen in the cortex (Fig. 2H,I). These longitudinal and transverse cell divisions modify the original single tier (based on a cell of the uniseriate filament) in forming two to four transverse tiers. Each medullary tier is overlain by two to four corresponding cortical tiers in the mature thallus (see isodiametric reconstruction, Fig. 2M–P).

Rosenvinge (1935) placed *Stictyosiphon adriaticus* Kuetzing *sensu* Kuckuck (1929, figs

121–125) and *S. corbieret* Sauvageau (1929) in *S. soriferus* because all three taxa agreed well with Reinke's *Kjellmania sorifera* Kuckuck's *S. adriaticus* did not show the hollow axes originally described for this species by Kuetzing. Feldmann (1937) added as further distinctions between *S. soriferus* and *S. adriaticus* that the cortical cells of the former were smaller (usually less than 30 μ m broad) than those of the latter (40–50 μ m broad) and that the phaeoplasts in *S. soriferus* are round while those of *S. adriaticus* are ovoid to elongate. Naylor (1958) used the seven distinctions given in Table 1 to separate the two species. The two European specimens (one of each species) determined by Feldmann confirm the distinctions made by Feldmann and Naylor.

Levring (1937) distinguished *Stictyosiphon subarticulatus* (Areschoug) Hauck (including *S. soriferus sensu* Rosenvinge 1935) from *Kjellmania sorifera* Reinke (1889) by the cortical sporangia protruding in the former and immersed in the latter. Rosenvinge & Lund (1947) consider that this character is not constant and consequently included *S. subarticulatus* in their concept of *S. soriferus* (Reinke) Rosenvinge.

The Australian collections agree most closely with *Stictyosiphon soriferus* (Reinke) Rosenvinge, but do not show intercalary plurilocular sporangia in uniseriate filaments, and sub-

cortical development is more extensive than described for European material.

Order DESMARESTIALES

The order is heteromorphic, the conspicuous sporophyte being characterized by the presence of a central axial filament developing from a distinctive intercalary meristem, and with opposite (or verticillate) branching producing a complanate thallus. The axial filament becomes surrounded by a medulla and a cortex formed by rhizoidal filaments arising in the meristematic zone at the emergent tip of the axial filament. The gametophyte is microscopic and oogamous. This order is represented in southern Australia by the cosmopolitan *Desmarestia ligulata* (Lightfoot) Lamouroux (Womersley 1967).

Both Fritsch (1945) and Sauvageau (1931) give detailed descriptions of development of cortex and medulla and comparison between members of the Desmarestiales.

Family DESMARESTIACEAE

ARTHROCLADIA Duby 1832: 18

Fritsch 1945: 180.

Thallus polystichous, slender and much branched, with long lateral branches arising irregularly but often oppositely, and fasciculate verticillate laterals which are determinate in growth. The cortex is rhizoidal in origin, arising at the bases of laterals, and branching to increase the cover over the central axial filament. The medulla, which arises by the inward periclinal division of the cells of the cortical rhizoids, is several layers thick in the mature axes with the largest cells nearest the axial filament. The lateral filaments do not retain a connection with the axial filament. The unilocular sporangia are formed in uniseriate filaments, of 6–30 subspherical sporangia, lateral to the main and secondary branches of the fasciculate laterals.

The life history suggested by Sauvageau (1931) involves the unilocular sporangia releasing zooids which settle singly to form a filamentous thallus. The new sporophyte arises directly from one of the cells of this supposed gametophyte, but Sauvageau's interpretation of oogonia and antheridia has been questioned (Fritsch 1945).

This monospecific genus is separated from *Desmarestia* on the basis of unilocular sporangia formed in filaments on the lateral branches and not in the cortex as in *Desmarestia*, and the fasciculate lateral branches which are determinate in growth, do not become secondarily corticated and are associated with the cortex rather than retaining a filamentous connection through the medulla to the axial filament. *Desmarestia* produces two kinds of gametophytes (Schreiber 1931) or bisexual gametophytes (Nakahara & Nakamura 1971).

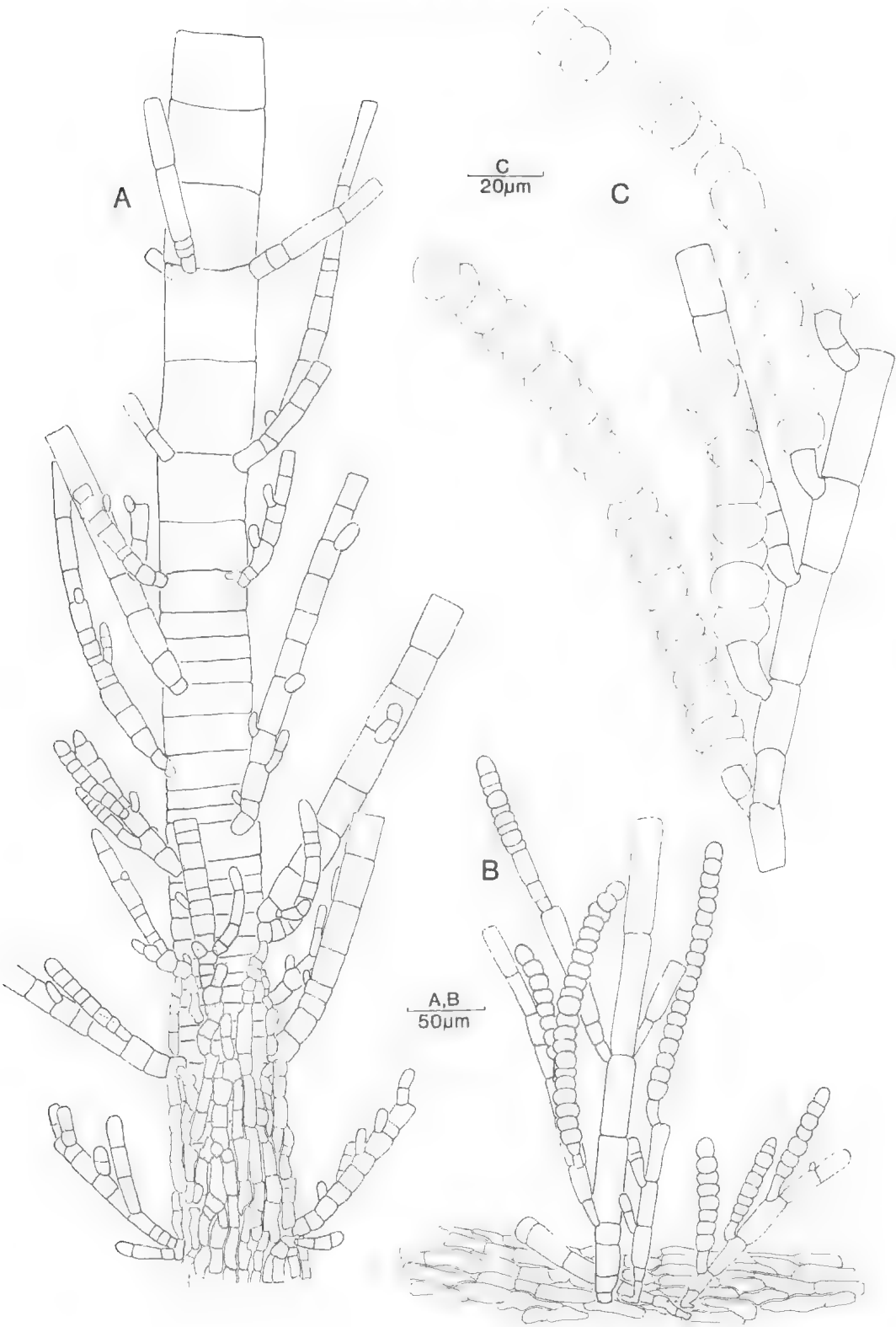
Arthrocladia villosa (Hudson) Duby 1832: 18. Fritsch 1945: 180, figs 60D, 61E, 62B. D.F.I.M. Rosenvinge & Lund 1943: 55. Sauvageau 1931: 95, figs 17, 18. Taylor 1937: 162, Pl. 13, fig. 2. Pl. 17, figs 7–8.

Thallus (Fig. 1C) olive brown, 15–20 cm tall, polystichous, terete and slender, much branched, with long lateral opposite branches and irregular, verticillate fascicles of short laterals, four fascicles per whorl, without phaeophytan hairs; holdfast not known from southern Australian material.

Erect axis with a large axial filament surrounded by a multicellular medulla derived by inward development of the cortex, and a peripheral rhizoidal cortex of one layer of photosynthetic cells. Growth and development markedly trichothallic; the meristematic zone of the axial filament a row of short broad cells at the point of emergence of the axial filament from the cortical envelope; axial filament emergent well beyond the meristematic zone, with whorls of four, narrower lateral filaments at intervals; lateral processes and rhizoidal initials arising from the axial cells at or below the meristematic zone, laterals arising before rhizoidal initials (Fig. 3A); cells of axial filaments increasing in length and breadth basally, 28–160 μm in diameter, L/B 2–3. Cortical cells irregular in shape, 9–12 μm in diameter, 2.5–4 L/B, with numerous small discoid phaeoplasts, filaments retaining a rhizoidal appearance and occasionally branching. Medulla of several layers, derived from periclinal division of cortical rhizoids, cells larger towards the centre, without phaeoplasts.

Lateral processes of two kinds; new lateral branch filaments sparsely branched initially and remaining dormant; determinate fascicu-

Fig. 3. A–C. *Arthrocladia villosa* (Huds.) Duby. (ADU, A52837). A. Meristematic zone of axial filament, with initiation of laterals and rhizoidal cortex. B. Mature rhizoidal cortex and determinate lateral filaments with filaments of unilocular sporangia. C. Filaments of unilocular sporangia, including two mature sporangia and two empty sporangia.



late laterals (Fig. 2B) much branched basally with a basal meristem, developing secondary filaments, cells cylindrical, 12–15 μm in diameter, L/B 1–4, with numerous discoid phaeoplasts and a prominent nucleus.

Reproduction. Unilocular sporangia (Fig. 3B,C) in moniliform, second filaments on determinate laterals, with a basal cell and 8–24 sporangia; each mature sporangium sub-spherical with lateral pore, 10–12 μm in diameter and L/B 1–1.5, with 16 zooids; maturation irregular and independent.

Type locality: Cornwall, England.

Type: Hudson (lost?) or BM (Dixon 1959, 1963).

Distribution: Temperate North Atlantic, Mediterranean.

In southern Australia, known only from Port Stanvac, S. Aust., 4–5 m deep, not

attached (Clarke, 28.xii.1981; ADU, A52837).

This occurrence, of free floating plants, is the first record of *A. villosa* for southern Australia. Port Stanvac is an oil refinery port where tankers dock, including ships which have come from European ports. It is not known whether *Arthrocladia* has (or will) become established on this coast, since the plants observed were not attached and only collected on the one occasion.

Acknowledgments

Appreciation is expressed to the Marine Sciences and Technologies committee for their support, to Dr G. Kraft of the University of Melbourne and Dr M. Clayton of Monash University for specimens or the loan thereof, and to Dr M. J. Parsons, D.S.I.R. New Zealand, for loan of specimens and for comments on the manuscript.

References

- CARAM, B. (1965) Recherches sur la reproduction et le cycle sexué de quelques Phéophycées. *Vie et Milieu* 16, 21–221.
- (1966) Sur la reproduction de deux Striaracées des eaux danolse. *C. r. Acad. Sc. Paris* 262, 2333–5.
- & NYGREN, S. (1970) A propos de la reproduction comparée en France et en Suède d'une Phéophycée—Pheosporée: le *Striaria attenuata* Helgol. wiss. Meeresunters. 20, 130–5.
- CLAYTON, M. N. & DUCKER, S. C. (1970) The life history of *Punctaria latifolia* Greville in southern Australia. *Aust. J. Bot.* 18, 293–300.
- DUBY, J. E. (1832) *Botanicon gallicum*. II. (Paris.)
- DIXON, P. S. (1959) Notes on two important algal herbaria. *Br. phycol. Bull.* 1(7), 35–42.
- (1963) Further comments on the typification of Hudson's Algae. *Ibid.* 2(4), 265–6.
- FEDMANN, J. (1937) Les algues Marines de la Côte des Albères. I–III. Cyanophycées, Chlorophycées, Phéophycées. *Rev. Algol.* 9, 141–335, pls 8–17.
- FIJOL, J. (1975) A new generic name for *Farlowiella onusta* (Phaeophyta). *Taxon* 24, 497–8.
- (1977) Life history and taxonomy of *Stictyosiphon subsimplex* Holden (Phaeophyta, Dictyosiphonales) and *Farlowiella onusta* (Kützinger) Kornmann in Kuckuck (Phaeophyta, Fétogeariales). *Phycologia* 16, 301–11.
- FRITSCH, F. E. (1945) *The Structure and Reproduction of the Algae*. II. (University Press; Cambridge.)
- GREVILLE, R. K. (1828) *Scottish Cryptogamic Flora*. (Edinburgh.)
- (1830) *Algae Britannicae*. (Edinburgh.)
- HAMEL, G. (1937) *Phéophycées de France III*, 177–240. (Paris.)
- KORNMAN, P. & SAHLING, P.-H. (1973) *Striaria attenuata* (Phaeophyta, Dictyosiphonales), neu bei Helgoland: Entwicklung und Aufbau. *Helgol. wiss. Meeresunters.* 25, 14–25.
- KUCKUCK, P. (1929). Fragmente einer Monographie der Phaeosporaceen. *Wiss. meeresunters.* N.F. 17(4), 1–93.
- KUETZING, F. T. (1843) *Phycologia generalis; oder Anatomie, Physiologie und Systemkunde der Tangen*. (Leipzig.)
- LEVING, T. (1937) Zur Kenntnis der Algenflora der Norwegischen Westküste. *Lunds Univ. Atsk. N.F.* 2, 33(8), 148 pp.
- NAKAHARA, H. & NAKAMURA, Y. (1971) The life history of *Desmaretia tabacoides* Okamura. *Bot. Mag. Tokyo* 84, 69–75.
- NYLOR, M. (1958) Observations on the taxonomy of the genus *Stictyosiphon* Kütz. *Rev. Algol.* 4, 7–24.
- NYGREN, S. (1975) Life history of some Phaeophyceae from Sweden. *Bot. mar.* 18, 131–41.
- REINKE, J. (1889) Algenflora der westlichen Ostsee deutscher Anthels. *Bericht Komm. wiss. Unters. deutsch. Meere Kiel*. 6.
- (1889–1892) *Atlas deutscher Meeresalgen. Komm. wiss. Meere*. (Berlin.)
- ROSENTHAL, L. K. (1935) On some Danish Phaeophyceae. *Mém. Acad. R. Sci. Lett. Dan. Copenhagen. Sect. Sci. Ser. 9*, 6(3), 40 pp.
- & LUND, S. (1943) The marine algae of Denmark. Vol. II. Phaeophyceae II. Corynophacaceae–Arthrocladiaceae. *K. Dan. Vidensk. Selsk. Biol. Skr.* 2(6), 59 pp.
- & — (1947) The marine algae of Denmark. Vol. II. Phaeophyceae III. Encoeliaceae–Laminariaceae. *Ibid.* 4(5), 99 pp.
- SAUVAGEAU, C. (1929) Sur le développement de quelques Phéosporées. *Bull. Stat. Biol. d'Archacchon* 30, 1–126.

- (1931) Sur quelques Algues phéosporées de la rade de Villefranche. *Ibid.* **28**, 7-165.
- SCHREIBER, E. (1932) Über die Entwicklungsgeschichte und die systematische Stellung der Desmarestiaceen. *Zeitschr. Bot.* **25**, 561-82.
- SKOTTSBERG, C. (1921) Botanische Ergebnisse der Schwedischen Expedition nach Patagonien und dem Feuerlande 1907-1909. VIII Marine Algae. I. Phaeophyceae. *K. svenska Vetensk-Acad Handl.* **61**(11), 1-56.
- SOUTH, G. R. & HOOPER, R. (1976) *Stictyosiphon soriferus* (Phaeophyta, Dictyosiphonales) from eastern North America. *J. Phycol.* **12**(1), 24-29.
- TAYLOR, W. R. (1937) *Marine algae of the north eastern coast of North America*. (University of Michigan Press, Ann Arbor.)
- WOMERSLEY, H. B. S. (1967) A critical survey of the marine algae of southern Australia. II. Phaeophyta. *Aust. J. Bot.* **15**, 189-270.

TRANSACTIONS OF THE
ROYAL SOCIETY
OF SOUTH AUSTRALIA
INCORPORATED

VOL. 107, PART 2

BENTHIC COMMUNITIES OF UPPER SPENCER GULF, SOUTH AUSTRALIA

BY S. A. SHEPHERD

Summary

Benthic communities in upper Spencer Gulf occupying an area of about 30 km² off Redcliff Point are described. There are six seagrass communities (*Zostera mucronata*, *Amphibolus antarctica*, *Heterozostera tasmanica*, *Halophila ovalis*, *Posidonia australis* and *Posidonia sinuosa*), two algal (*Caulerpa cactoides* and Red Algae) and three animal assemblages (Sponge-Telesto, Polycarpo-Echinogorgia, and Lanceopora-Sycozoa). The distribution and density of the dominant species along five transects is described, and the distribution of seagrasses and assemblages near Redcliff Point mapped.

BENTHIC COMMUNITIES OF UPPER SPENCER GULF, SOUTH AUSTRALIA

by S. A. SHEPHERD*

Summary

SHEPHERD, S. A. (1983) Benthic communities of upper Spencer Gulf, South Australia. *Trans. R. Soc. S. Aust.* **107**(2), 69-85, 31 May, 1983.

Benthic communities in upper Spencer Gulf occupying an area of about 30 km² off Redcliff Point are described. There are six seagrass communities (*Zostera mucronata*, *Amphibolis antarctica*, *Heterozostera tasmanica*, *Halophila ovalis*, *Posidonia australis* and *Posidonia sinuosa*), two algal (*Caulerpa racetoides* and Red Algae) and three animal assemblages (Sponge—*Telesto*, *Polysarpa-Echinogorgia*, and *Lanceopora-Syracosa*). The distribution and density of the dominant species along five transects is described, and the distribution of seagrasses and assemblages near Redcliff Point mapped.

Although somewhat impoverished in number of species compared with oceanic coasts, the algal flora has predominantly cool temperate affinities; only four species are of tropical or warm temperate origin. The benthic epifauna is also impoverished in number of species but has unique characteristics. Some species appear to be endemic to the region while others, of cosmopolitan or tropical affinities, are known in South Australia only from the region.

KEY WORDS: benthic communities, seagrasses, algal flora, animal assemblages, upper Spencer Gulf.

Introduction

The upper parts of Spencer Gulf and Gulf St Vincent experience high summer temperatures, high evaporation rate and little or no fresh water inflow. They are characterised by hypersaline waters and wide sea temperature extremes, and (together with Shark Bay, Western Australia) have been described as negative estuaries (Davies 1970, Bayly 1975).

The upper regions of these gulfs are important as spawning or nursery areas for the western king prawn *Penaeus latissulcatus* Kishinouye as well as for numerous species of scale fish of commercial interest (King¹; Jones²), and a part of upper Spencer Gulf has been declared an aquatic reserve for their protection. For these reasons alone they deserve more attention. Furthermore, conflicting use of the regions, especially of upper Spencer Gulf, as receptacles for industrial and urban wastes and for thermal discharges adds urgency to the need for further baseline studies.

This paper describes the major benthic communities in upper Spencer Gulf near Redcliff Point, and is a result of surveys in 1973, 1974 and 1980. The only general descriptions of the biology of this region are by Shepherd (1974) for Crag Point and Johnson³ for seagrass epiphytes on *Posidonia* off Redcliff Point. There is also a brief study on the

growth of *P. australis* near Redcliff Point by West & Larkum (1979). Mangroves of the region are described by Butler *et al.* (1977) and those specifically around Redcliff Point by Chinnoek (1980), and Beanland & Woelkerling (1982) have described the mangrove algal flora of upper Spencer Gulf. Hails *et al.* (1980) have given a preliminary account of the sediments of upper Spencer Gulf.

Methods

In September, 1973, studies were made along six transects across the Gulf. The positions of five are shown in Fig. 1; another, about 1 km north of No. 2 transect, gave similar results to No. 2 transect and is not shown. A two-man sled (Fig. 2) carrying a driver and an observer was towed over the bottom at a speed of about 1.5 knots (80 cm/sec).

Stations were occupied at intervals of about 300-400 m when the towing vessel stopped and the divers made collections of epibenthic organisms and took underwater photographs.

¹ King, M. G. (1979) The biology of the Western King Prawn *Penaeus latissulcatus* Kishinouye and aspects of the fishery in South Australia, 167 pp. M.Sc. Thesis, Dept. of Zoology, University of Adelaide, unpubl.

² Jones, G. K. (1979) Biological investigations on the marine scale fishery in South Australia, 72 pp. Dept. of Agric. & Fisheries, Adelaide, unpubl.

³ Johnson, J. E. (1981) The seasonality of the algal epiphytes of *Posidonia sinuosa* in upper Spencer Gulf, 283 pp. M.Sc. Thesis, Dept. of Botany, University of Adelaide, unpubl.

* Department of Fisheries, 25 Grenfell Street, Adelaide, S. Aust. 5000

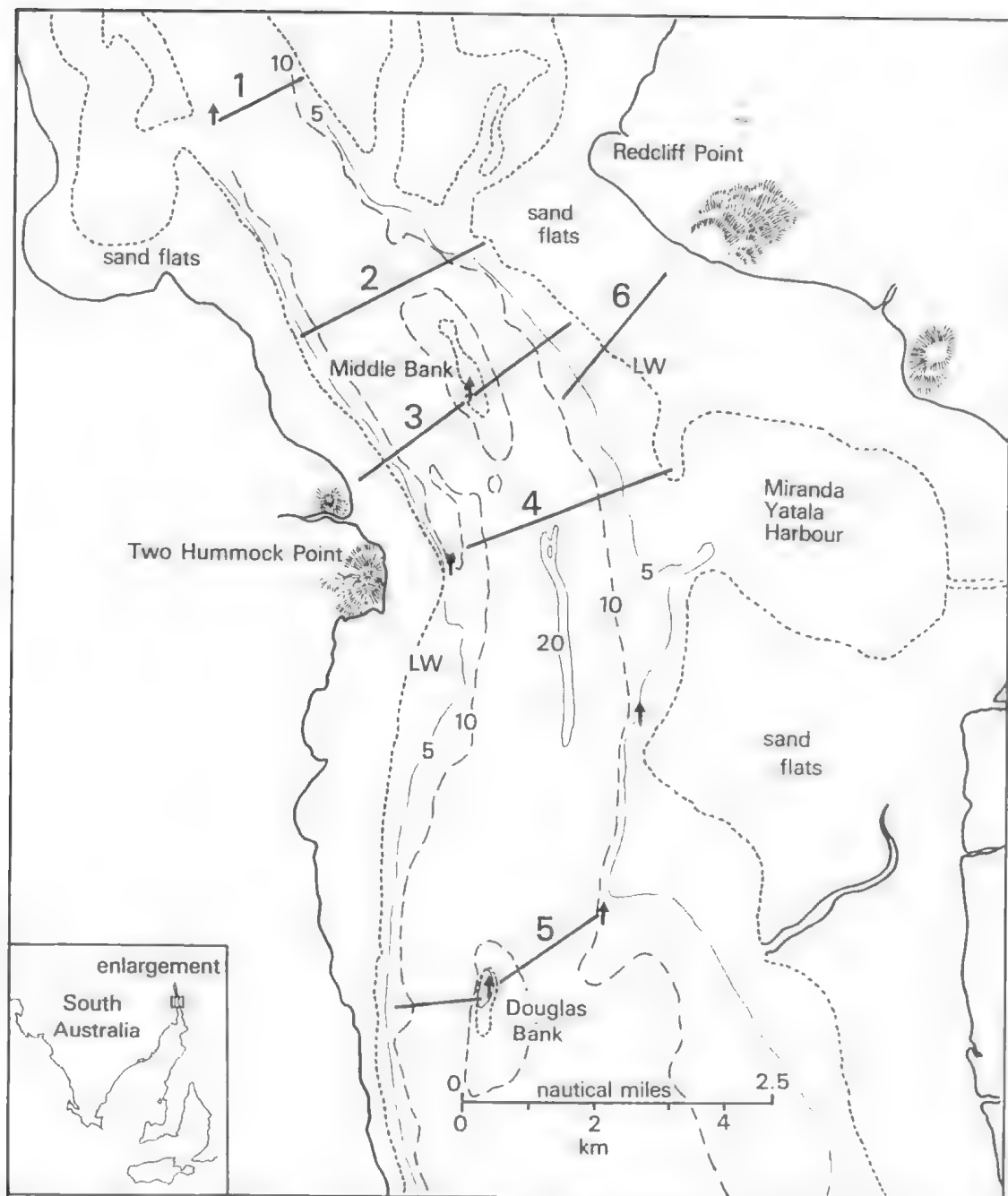


Fig. 1. Upper Spencer Gulf showing transect lines and depth contours (in metres). Beacons are the solid triangles over a vertical line, LW = Low water mark.

The diver can see below, through a rectangular section of the frame of the sled, an area of about 1 m^2 of the bottom. This framed area was used during sled runs to estimate the percentage cover of algae and densities of common epibenthic animals. These density

estimates were verified at stations, where counts were made over an area of 10 m^2 measured by using the side of the sled (2 m) and a 1 m stick.

In April 1980, four additional runs were made longitudinally down the eastern channel



Fig. 2. Underwater sled showing diver fixing collecting bags at stern. Writing slate is fixed to right hand diver's position.

basin (i.e. that on the eastern side of Middle Bank), and 5–8 stations occupied at about equal intervals on each run. The positions of these stations were fixed using "Decca" position-fixing equipment.

Data were recorded on a slate and collections were placed in bags fixed to the sled's stern. Depth was recorded by echosounder on board the towing vessel and later adjusted to low water datum i.e. Indian Spring Low Water (LW) of Department of Marine & Harbours (DMH). Subsequently, further sled runs were made in the western channel to complete the mapping and to fill gaps. Sidescan sonar data (Hails *et al.* 1980) were used to further define the distribution of sandwaves.

In January 1974, a transect (No. 6 in Fig. 1) was made across the eastern sublittoral platform from the shoreward edge of the *Zostera* beds (referred to later as 'shore datum' being 700 m from high water mark) to a depth of 8.4 m. A weighted polypropylene line was laid along the transect, and the line intercept procedure was used to record the distribution and cover of seagrasses. The diver swam along the line recording for each 5 m interval the species intercepted by the line and, where mixed stands occurred, the proportional cover of each species under the line. Similar data were recorded at distances of 1600 m, 2200 m, 2500 m and 2800 m respec-

tively, from shore datum along additional cross-transects each of 500 m length laid at right angles to the principal transect.

On the western side of the Gulf at the beacon near Two Hummock Point four transects, each 250 m long, were laid in seagrasses parallel to the shore at uniform depths of 1.4 m, 2.4 m, 3.4 m and 4.4 m depths respectively, and data on distribution and cover obtained.

Seagrasses were harvested at the sand-line at steps along each transect from four 0.25 m² quadrats placed at random on the sea floor. The material collected was preserved in 5% formalin solution, and later weighed fresh in the laboratory to give above-sand standing crop data. The length and width (measured 15 cm from the base) of the blade of *Posidonia australis* and *P. sinuosa* were measured from a sub-sample (N = 50) of each collection.

In preparing the maps, aerial colour photographs (taken in 1980) of the Department of Lands were used to plot the landward boundary of seagrasses and other features, and precision DMH depth charts were used to plot depth contours.

Epibenthic organisms collected for identification included seagrasses and algae, and animals in the phyla Cnidaria, Annelida, Bryozoa, Echinodermata, Mollusca, Crustacea and Chordata (Ascidiacea). No attempt was made to collect pelagic or vagile species within these phyla. In addition, observations were made on the presence and abundance of fish.

Description of region

The upper part of Spencer Gulf (Fig. 1) has a narrow channel basin, generally 15–20 m deep, divided into eastern and western channels by Middle Bank and further south by Douglas Bank. On either side of the channel basin are shallower sublittoral platforms colonised by seagrasses. The platform on the western side of the Gulf is very narrow, seldom more than 200 m wide, whereas that on the eastern side may exceed 2 km in width. These features are illustrated by the bottom profiles in Figs 5–8. Broad intertidal-supratidal platforms (shown in Fig. 1 as sand flats) flank the channels and are colonised up to about 1.5 m above LW i.e. to about mean sea level (MSL) by *Zostera mucronata*.

Tributary channels up to 8 m deep cross the intertidal platforms on the eastern side of

the Gulf, and connect to the numerous mangrove creeks north of Redcliff Point. Mangrove thickets are well developed on the eastern shore but are less extensive on the western shore (Butler *et al.* 1977).

The annual temperature range off Redcliff (near Middle Bank Beacon) is from about 11.5°C (winter) to 26°C (summer) and the annual salinity range is from about 41.5‰ (winter) to 45.5‰ (summer). Monthly temperature and salinity data for upper Spencer Gulf for 1975–1978 are given by Johnson (1981).

Water transparency off Redcliff was measured for 3½ years (1975–1978) at monthly intervals in the channel near Middle Bank by noting the depth of disappearance of a Nansen bottle (N) used for water sampling (Johnson 1981). The data were transformed to Dsd (depth of disappearance of a standard Secchi disc) using the following formula derived from comparative data taken at the site:

$$\text{Dsd} = 1.93 \text{ N} - 0.72 \quad (r^2 = 0.99; N = 10)$$

The inverse correlation of Dsd with sea state⁴ was tested using the Spearman rank correlation coefficient and was found to be significant ($r = -0.36$, $P < 0.05$).

According to J. E. Johnson (pers. comm.) sea state on the previous day, season and tide each affect water transparency in a complex way. Dsd data (giving water attenuation coefficient values obtained from the conversion formula of Weinberg (1976) are plotted in Fig. 3 and illustrate the wide variation in water transparency.

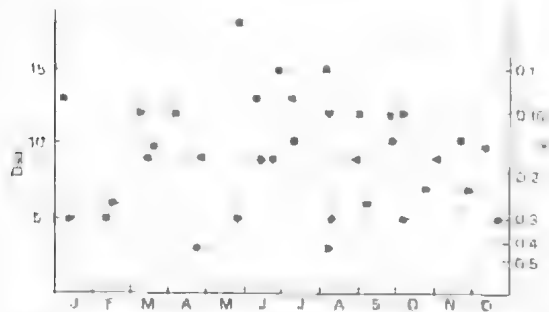


Fig. 3. Calculated depth of disappearance of secchi disc (Dsd) and attenuation coefficient of seawater (K) at station near Middle Bank during 1975–8. Dsd scale is in metres.

Water movement in upper Spencer Gulf arises from tidal currents and wind-driven wave action. The pattern of tides is mixed semi-diurnal with a tidal period of about 12½ hours and a maximum tidal range of about 3 m. Mean sea level changes may vary the astronomical tidal extremes by up to 2 m (Provis & Radok 1979, Radok, pers. comm.). Tidal currents to one m/sec. occur in the channels although actual currents near the bottom were considerably less than this according to divers' estimates. Prevailing winds are northerly or southerly and may generate short period (i.e. < 6 sec.) waves up to 2 m high in the channels. Wave action on the shallow sublittoral platforms is therefore likely to be considerable especially after the development of rough local seas, but is of little or no significance on the sea floor in the channels.

Water movement was measured along Transect 6, and on the transects near No. 1 Beacon using "Doty" plaster clod cards (Doty 1971, Shepherd 1974) fixed to stakes driven into the sediment. The clod cards were placed at a level just above the tips of the seagrass. The results expressed in DIF units⁵ give a relative measure of water movement arising from the combined effect of wave action and current.

The experiments were done on 6–7 January 1976 over 24 hours when there were light southerly winds in the morning and a sea-breeze in the afternoon. The results (incorporated in Figs 9, 10) show that while water movement is greatest in shallow water and declines slightly with depth on the western shore, there is a reverse trend with water movement increasing slightly with depth on the eastern shore.

Similar experiments by J. E. Johnson (pers. comm.) in calm weather in October 1975 gave the following DIF values for the eastern shore near Transect 6.

2 m depth — 20.8; 7 m depth — 22.6 10 m depth — 23.8, showing a similar trend for increasing values with increasing depth.

The results contrast with those of open coasts, (e.g. Shepherd & Womersley 1981) where water movement declines sharply with depth, and demonstrate the importance of tidal currents in this region.

⁴ On the Beaufort scale, sea state is given a numerical value according to wave height as follows: 0 = calm; 1 = 30 cm; 2 = 30–90 cm; 3 = 90 cm–1.5 m; 4 = 1.5–2.4 m.

⁵ DIF = diffusion increase factor. The unit is the loss of weight of the clod card relative to the loss of weight in still water. See Doty (1971) and Shepherd (1974).

Distribution and density of benthic organisms

The distribution of density of the common epibenthic animals, the occurrence of the sponge—*Telesto* community (see below) and of seagrasses, and the percentage cover of algae are shown for Transects 1–5 in Figs 4–8.

Sand waves occurred on most transects and their location on each transect is also shown in the figures. Mean densities of common animals on three runs in the Eastern Channel are given in Table 3. Densities varied within and between runs but no correlation was evident between species' densities and depth or any other measured factor.

The distribution of mean percentage cover of seagrasses for the eastern and western sides of the Gulf is shown in Figs 9, 10. There are eleven conspicuous community-types. They are

six seagrasses, a *Caulerpa*, a red algal and three animal assemblages. The term 'assemblage' is used to mean broad species groupings without implication of biological inter-relations. The seagrasses and *Caulerpa* occur for the most part as monospecific stands with abrupt boundaries between species. Since the distributions of epibenthic animals may be more or less continuous, the recognition of assemblages is to some extent subjective; following Peterson's concepts, the most conspicuous and most numerous species are chosen to designate an assemblage (Thorson 1957). The seagrasses and assemblages for the region adjacent to Redcliff are described below, and their distributions mapped in Fig. 11.

1. *Zostera mucronata*

Monospecific stands of this species occur on both sides of the Gulf. On the eastern side

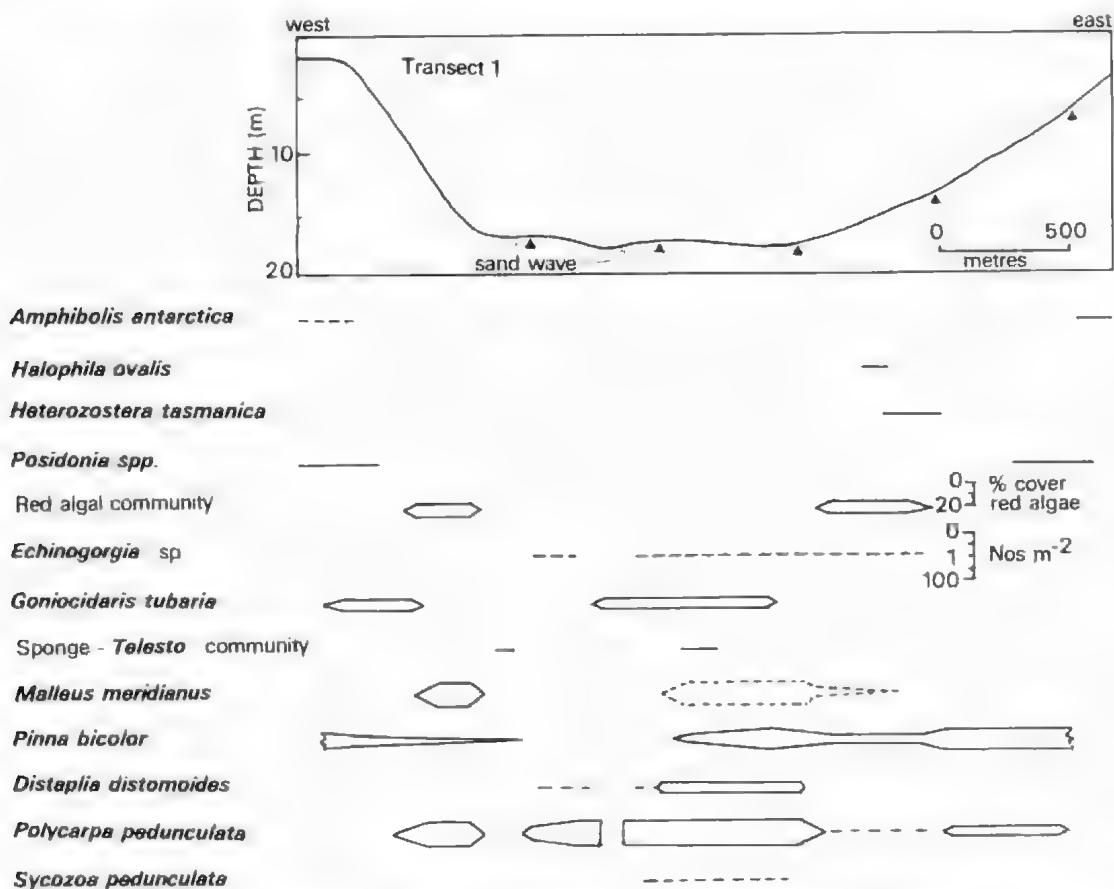


Fig. 4. Cross-section of Spencer Gulf along Transect 1 showing distribution of density of species or communities and distribution of sandwaves. Continuous line indicates a more or less uniform distribution; dotted line a patchy distribution. Scale of abundance is logarithmic for animals; percentage cover is given for algae. Sampling stations are shown by solid triangles.

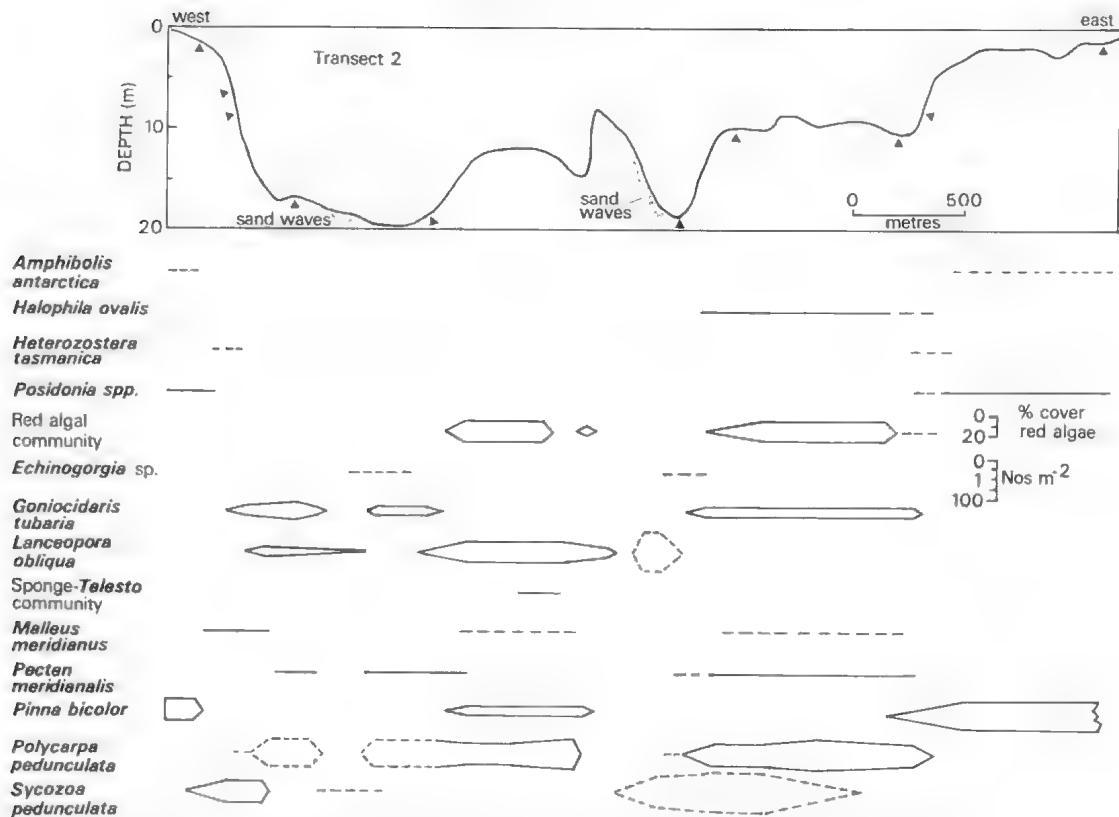


Fig. 5. Cross-section of Spencer Gulf along Transect 2. See caption to Fig. 4 for details.

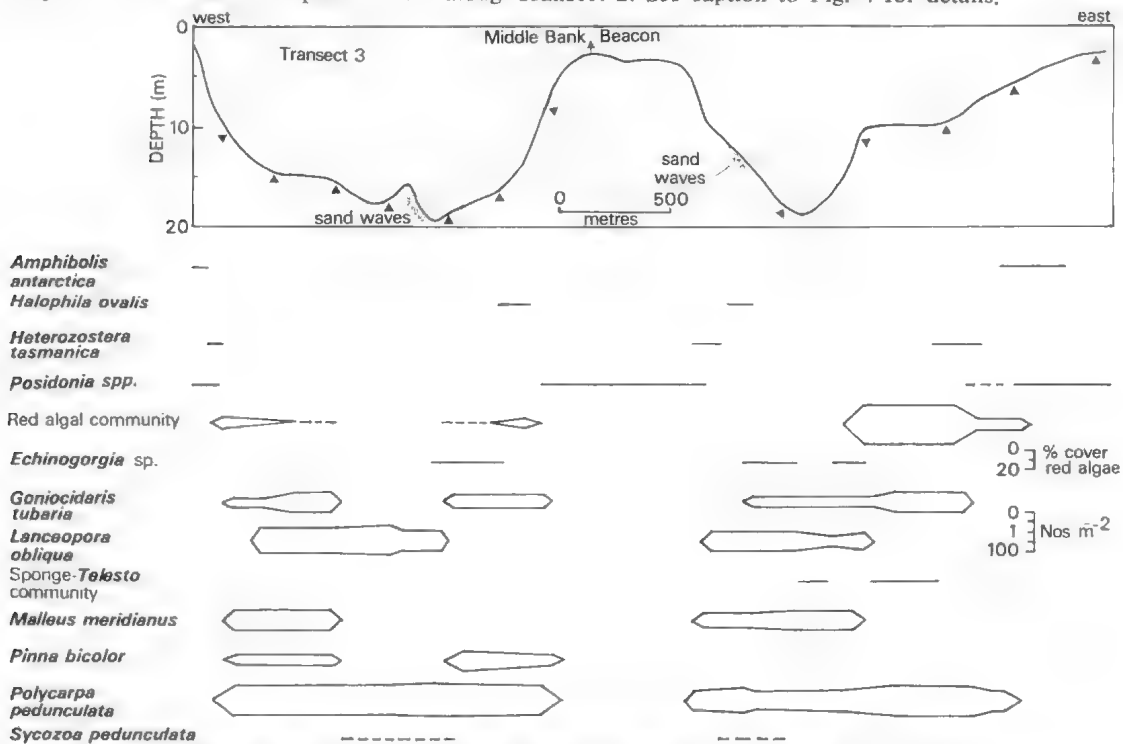


Fig. 6. Cross-section of Spencer Gulf along Transect 3. See caption to Fig. 4 for details.

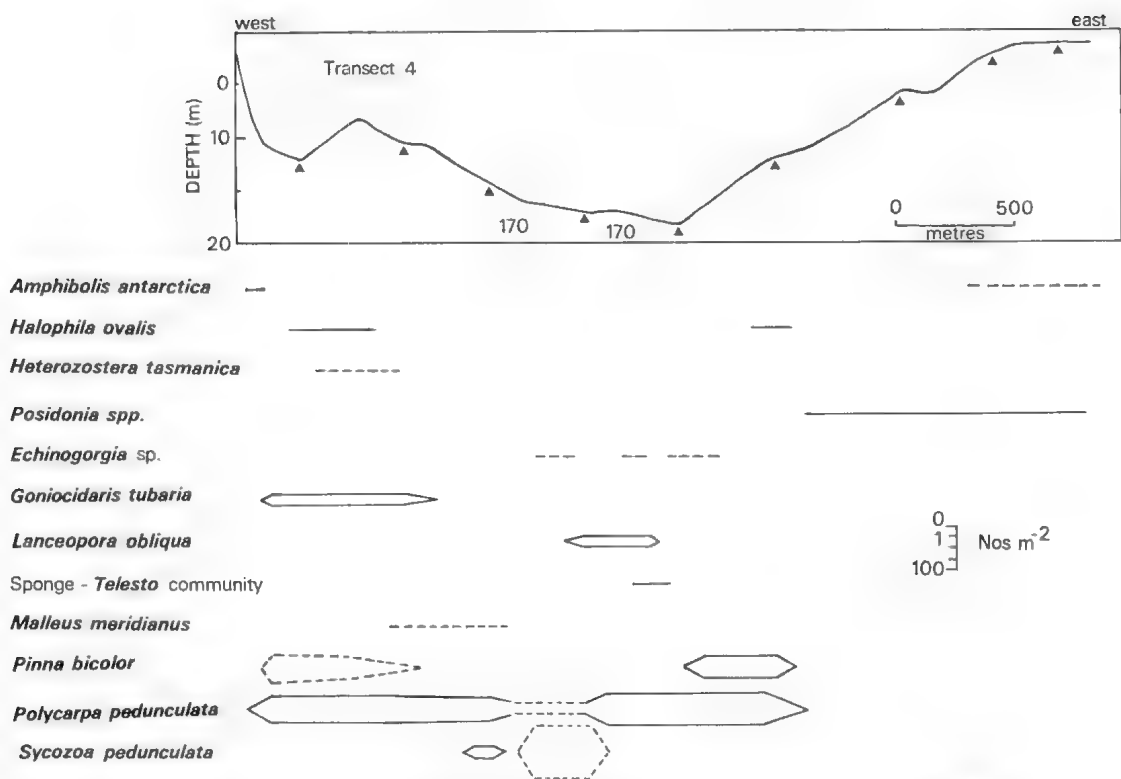


Fig. 7. Cross-section of Spencer Gulf along Transect 4. See caption to Fig. 4 for details.

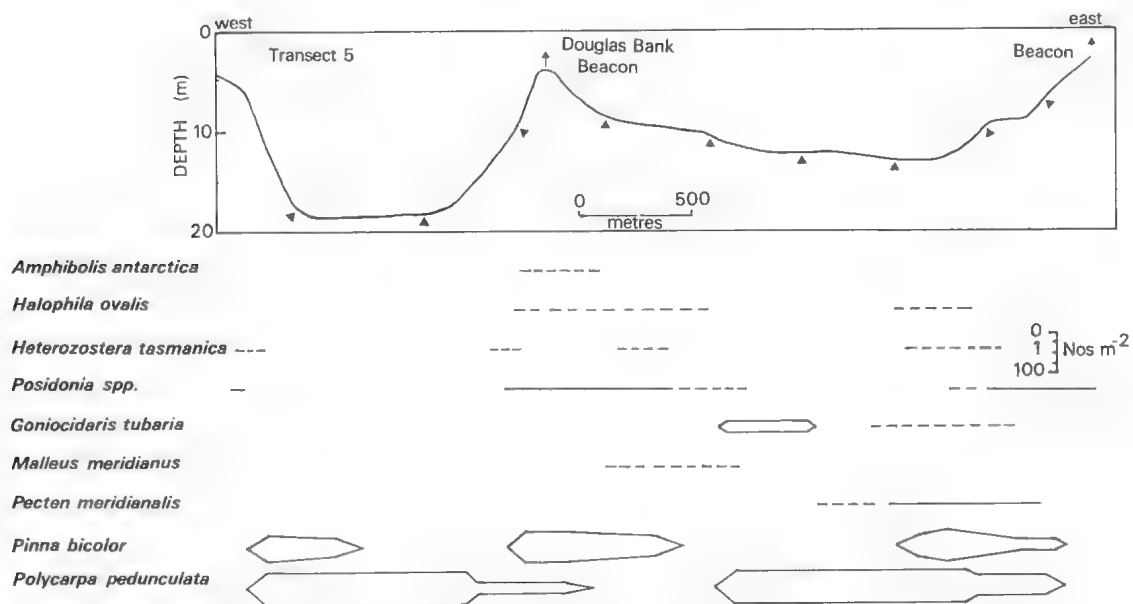


Fig. 8. Cross-section of Spencer Gulf along Transect 5. See caption to Fig. 4 for details.

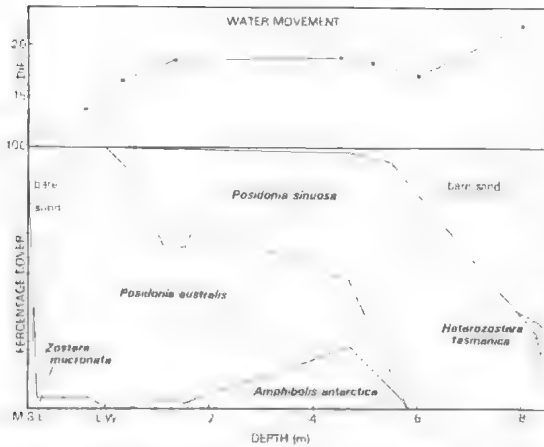


Fig. 9. Distribution of mean percentage cover of seagrasses with depth on the eastern shore of upper Spencer Gulf along Transect 6.

there is a distinct band at about MSL, with small patches occurring down to LW (Fig. 9). On the western side only scattered patches occur above LW. Biomass data were not obtained.

Stands near the species' upper limit at MSL suffered some dieback in the hot summer of

1980-81, but according to fishermen's reports completely recovered during the following winter.

2. *Posidonia australis*

Monospecific meadows of this species occur from a little below MSL to about 0.5-0.7 m deep and below this mixed with *Posidonia sinuosa* to about 6 m deep on the eastern side of the Gulf. On the western side mixtures of the two species do not occur, and monospecific clumps of *P. australis* occur to about 5 m deep.

Changes in standing crop, stand height and blade width with depth are given in Table 1. Standing crop values (for the eastern shore) and blade width values (for both shores) differed significantly between adjacent depth sites, with $t > 4$ and $P < 0.001$ in all cases. Differences in stand height between sites were tested statistically using the non-parametric k-spillage test which places heavy reliance on extreme values i.e. maximum blade length (Conover 1971). On each shore the low stand height values (i.e. those 36 cm or less) recorded for shallow water sites were each significantly less than the values for deeper sites ($P < 0.001$).

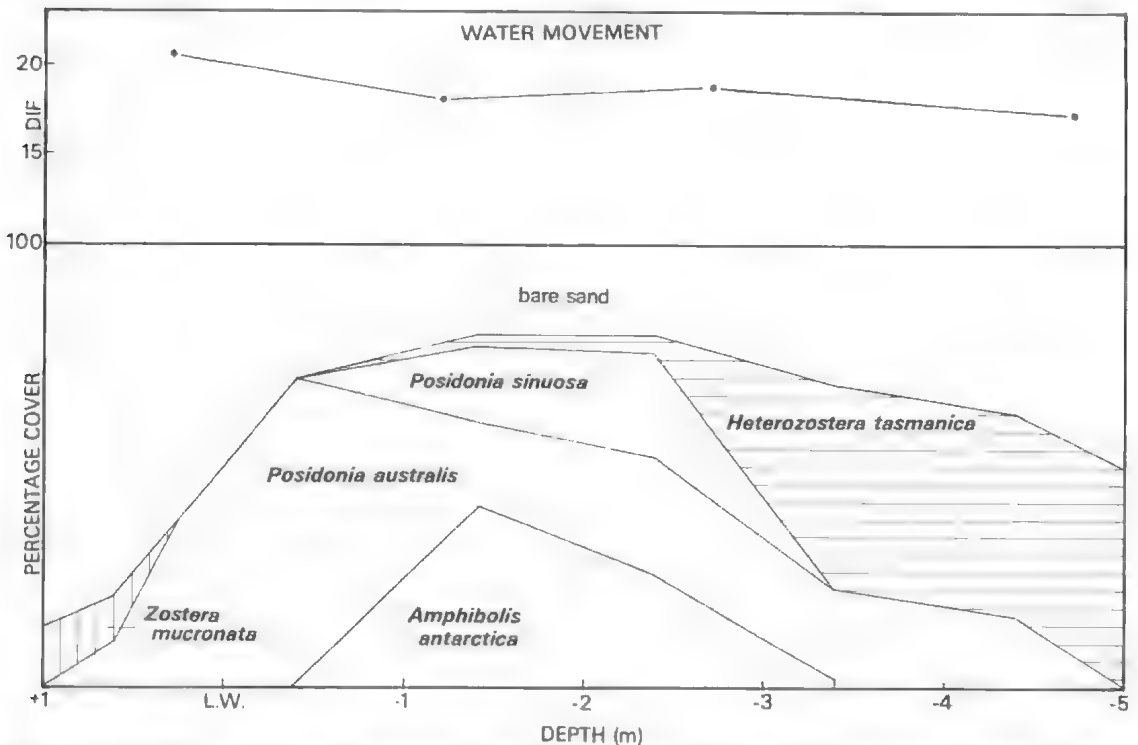


Fig. 10. Distribution of mean percentage cover of seagrasses with depth on the western shore of upper Spencer Gulf at No. 1 Beacon (near Two Hummock Point).

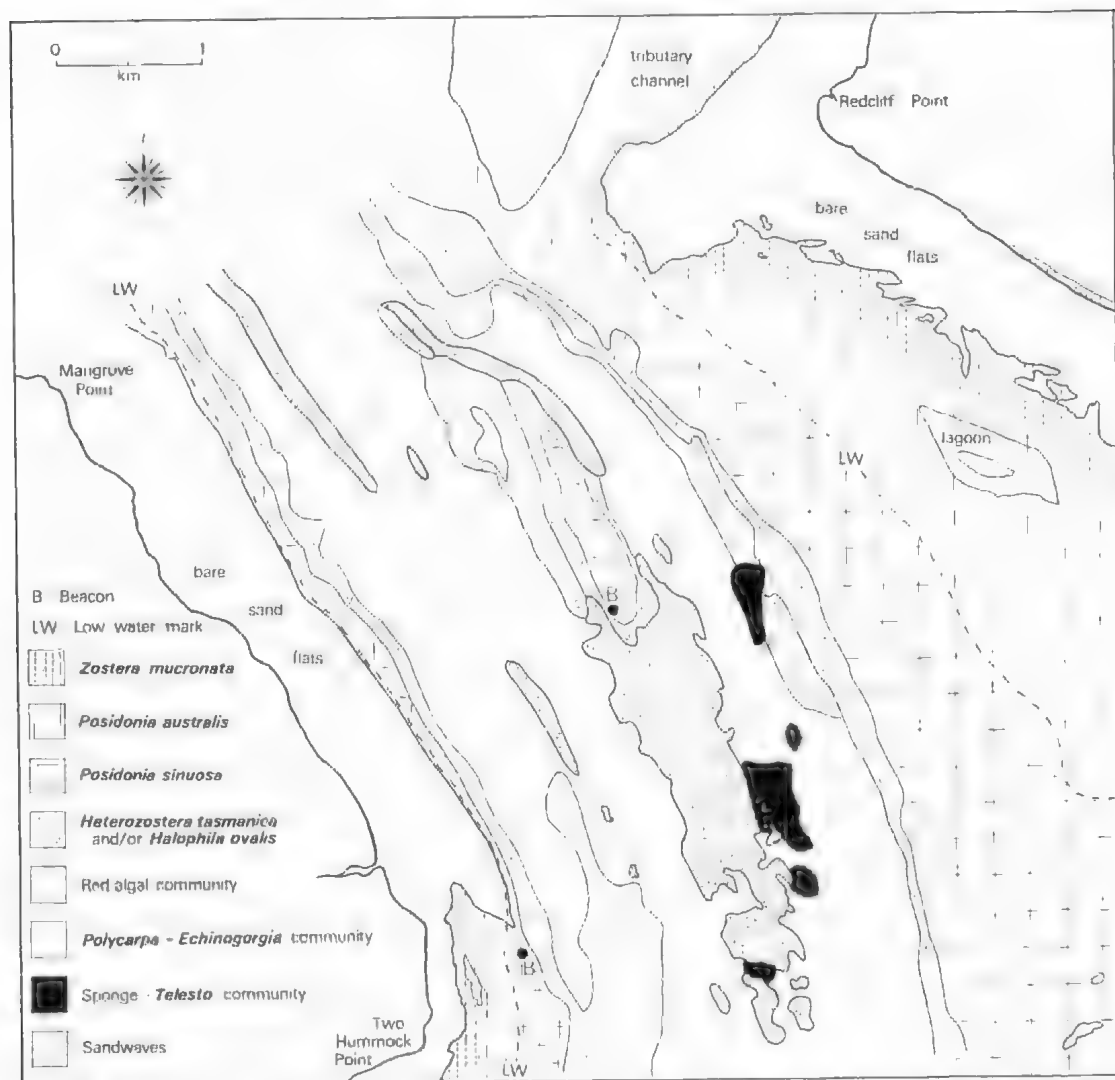


Fig. 11. Distribution of epibenthic assemblages in upper Spencer Gulf near Redcliff Point. B Beacon. LW = Low water.

Except for samples taken in a lagoon isolated at LW from Gulf waters on the eastern side, standing crop values decline with depth, while blade width and stand height increase. On the western side standing crop is variable but blade width and stand height both tend to increase with depth.

3. *Posidonia sinuosa*

This species occurs as monospecific stands on the western side of the Gulf to about 3.5 m deep, and on the eastern side in mixed stands with *P. australis* from 0–6 m deep, and as a monospecific community to about 8.3 m deep. On Middle Bank monospecific stands go

to about 7 m depth and further south at Douglas Bank to about 10 m depth.

Changes in standing crop, stand height and blade width with depth are given in Table 2. Standing crop values differ significantly ($t > 3.1$; $P < 0.02$) between shallow (–0.6 and –1.6 m), medium (–4.7 and –5.7 m) and deep (–8.3 m) sites, and stand height is significantly less ($P < 0.001$) for the –0.6 m and –8.3 m depth sites than the others, using the k-spillage test referred to above. Differences in blade width on the eastern shore between the extremes are significant ($t = 4.39$; $P < 0.001$) but not between populations of neighbouring depth stations. Blade width

TABLE 1. Changes in standing crop, in grams fresh weight (GFW), stand height and blade width of *Posidonia australis* at various depths along transects on eastern and western shores.

Depth (m)	Standing crop (GFW per 0.25 m ² (\pm 1 S.D.))	*Stand height (cm)	Mean blade width (mm) (\pm 1 S.D.)
Eastern shore:			
+ 1.3	550 (99.1)	29	7.5 (1.3)
- 1.4 (lagoon)	346 (129.7)	86	13.1 (1.1)
- 4.4 (lagoon)	49 (16.8)	69	11.4 (2.0)
+ 0.6	464 (106.0)	36	10.6 (1.1)
- 1.6	366 (103.7)	62	11.2 (1.5)
- 1.6	86 (23.2)	56	11.9 (0.9)
Western Shore:			
+ 0.6	266	27	8.9 (1.1)
- 0.4	410	36	9.8 (1.1)
2.4	237	71	9.3 (1.3)
- 3.4	455	67	11.4 (1.1)

* Stand height is the mean height of the upper third of the blades.

TABLE 2. Changes in standing crop, stand height and blade width of *Posidonia sinuosa* with depth on eastern and western sides of Spencer Gulf.

Depth (m)	Standing crop (GFW per 0.25 m ² (\pm 1 S.D.))	*Stand height (cm)	Mean blade width (mm) (\pm 1 S.D.)
Eastern shore:			
- 0.6	692 (201.4)	45	7.2 (1.5)
- 1.6	531 (136.2)*	57	6.9 (0.8)
- 1.6	569 (131.8)	54	7.0 (0.8)
4.7	274 (87.0)	56	7.4 (0.7)
- 5.7	283 (101.1)	58	7.6 (0.7)
8.3	15 (8.6)	33	6.9 (0.4)
Western Shore:			
- 2.4	424	81	8.5 (0.7)

* Mixed population with *P. australis*.

of the western shore population is significantly wider than the nearest (in width) eastern shore population ($t = 6.81$; $P < 0.001$) and significantly narrower than the nearest (in width) western shore population of *P. australis* ($t = 2.12$; $P < 0.05$). Overall, standing crop values decline with depth, blade width shows a trend of increasing blade width with depth (except for the deepest sample at the species' lower depth limit) and stand height tends to decrease at the species' upper and lower limit.

4. *Amphibolis antarctica*

Monospecific stands occur to a depth of about 5.5 m. However, standing crop values on the eastern shore (to 3 kg/m²) are con-

siderably higher than those on the western shore (to 800 g/m²).

5. *Heterozostera tasmanica*

A distinct band is common below *P. sinuosa* from 7-9 m depth. Standing crop values are 600-700 g/m².

6. *Halophila ovalis*

Stands of this species occur only at 8-10 m depth. Standing crop values (including below ground parts) of 105 g/m² were recorded at 10 m depth.

7. *Caulerpa cactoides*

Stands occur sparsely at depths of about 10 m on the edge of the channel predominantly on the western side of the Gulf. It was not investigated in detail and was of too limited an extent to be mapped.

8. Red algal assemblage

A diverse assemblage of red algae occurs on rocky bottom, attached to shell fragments or epiphytic on *Pinna bleclor* or clumps of *Mallens meridianus* from 8-12 (-16) m depth. The lower depth limit of attached algae is about 12 m on rocky bottom, although algae may rarely be found to 16 m on sandy bottom, probably due to the increased light reflected from the sand surface. A full species list with data on depth range and location is included in Appendix 1. Changes in percentage cover on Transects 1-3 are given in Figs 4-6.

Animal assemblages

A species list of all animals recorded during the various studies is given in Appendix 2.

9. Sponge—*Telesto* assemblage

Restricted to rocky substrate which either outcrops or is covered by a thin layer of sediment. The reef base is partly biotic since aggregations of the hammer oyster *Mallens meridianus* occur cemented together and increase the available firm substrate for the attachment of sessile fauna.

Detailed studies of the habitat have not been made, but the following species are conspicuous and common.

Porifera	— Many unidentified species
Cnidaria	— <i>Telesto multiflora</i> <i>Euplexaura</i> sp. <i>Echino-</i> <i>gorgla</i> sp
Annelida	— <i>Chaetopterus vario-</i> <i>pedatus</i>
Echinodermata	— <i>Anthaster valvulatus</i> <i>Goniodactylus tubarin</i>

Bryozoa	— <i>Celleporaria fusca</i> <i>Amathia brongniartii</i>
Mollusca	— <i>Malleus meridianus</i>
Chordata	— <i>Halocynthia hispidula</i>
(Ascidacea)	<i>Polycarpa pedunculata</i>

This habitat also attracts many fish of 11 species for which data are provided in Appendix 3.

10. *Polycarpa-Echinogorgia* assemblage

Occurs in the channel basin from (8–) 10–20 m deep on shelly or sandy bottom. The principal species are given in Table 3 with mean densities recorded during sled runs in the eastern channel basin. Other rarer species encountered are the seapens *Scytalium* sp. and *Virgularia mirabilis*, the hammer oyster *Malleus meridianus*, and the sea-star *Anthaster caliculatus*.

TABLE 3. Mean densities of organisms (in numbers/m² (with standard deviations where obtained) in the eastern channel basin.

Run No.	1	2	3
<i>Echinogorgia</i> sp.	1.7 (0.9)	1.0	<0.1
<i>Euplexaura</i> sp.	0.1	0.05	—
<i>Goniocidaris tubaria</i>	0.1	0.1	—
<i>Lanceopora obliqua</i>	0.2	0.1	0.4
<i>Polycarpa pedunculata</i>	8.5 (2.1)	6.2 (2.8)	12.8 (6.7)

11. *Lanceopora-Sycozoa* assemblage

Largely restricted to sandwaves. The principal species *Lanceopora obliqua*, *Sycozoa pedunculata*, *Polycarpa pedunculata* and *Virgularia mirabilis*, each have adaptations allowing them to persist in a mobile substrate. The first three have peduncles or stems up to 20 cm long attaching them deeply in the substrate while *Virgularia* has a long slender stalk, swollen basally, by which it moves vertically in the substrate. *L. obliqua* and *S. pedunculata* occur in aggregations in densities to 100/m² and *P. pedunculata* to densities of 10/m². The distribution of these species is crudely related to the mobility of the substrate. They are absent or occur in low abundance on the peaks of sandwaves, but occur in the recorded densities on the slopes and in troughs. The fauna of sandwaves are described in more detail elsewhere. (Shepherd 1983).

12. *Pinna bicolor* and *Malleus meridianus* aggregations.

Populations of *P. bicolor* with densities of up to 16/m² occur from the intertidal to 20 m

deep, but are most commonly found on the edges of the channel basin from 8–15 m (Figs 4–8). Intertidal populations (usually with the epizoaic alga *Hormosira banksii*) are common on "promontory" sand-pits jutting into the Gulf between Redcliff Point and Blanche Harbour but are rare elsewhere in the region studied (J. E. Johnson pers. comm.)

Populations of *M. meridianus* are even more irregular in their distribution than *P. bicolor* and occur mainly at 8–16 m depth.

Due to the uncertain occurrence of these species over broad depth ranges and in several community types, and their probable irregular recruitment (e.g. Butler & Keough (1981) for *P. bicolor*), they probably are best designated as facies of other assemblages in which they are found rather than as distinct units.

Discussion

These data represent the first account of the distribution of benthic communities and the abundance of organisms in upper Spencer Gulf. The description is incomplete since the infauna was not examined and the rocky bottom fauna was only studied superficially.

Environmental Factors

The underwater light climate is very variable with 'average' conditions low compared with those on open coasts (Shepherd & Womersley 1970, 1971, 1976, 1981); light may be an important factor causing stratification of the various seagrasses and red algal assemblage within the sublittoral (photic) zone and separating them from the deeper animal communities of the circalittoral zone. The role of water movement is more complex since it may affect organisms directly, and indirectly by influencing sediment characteristics. Thus differences in water movement between eastern and western shores may be responsible for the different sediment characteristics and hence the different distributions of seagrasses (see below). Differences in current velocities in the channel appear to be responsible for the distribution of sandwaves and their fauna (unpublished data).

Seagrasses

Posidonia australis and *P. sinuosa* are especially vigorous in South Australia (den Hartog 1970) and form lush beds of high productivity in upper Spencer Gulf (West & Larkum 1979, Johnson²). Assuming a blade

turnover rate of 3–4 per annum (West & Larkum 1979) then annual productivity would exceed 9 kg (fresh wt)/m² in shallow water, a value which equals that of many highly productive terrestrial and aquatic plant communities (Westlake 1963).

Blade width and blade length measurements were undertaken in order to better define the variation in the two *Posidonia* species, and as a means of distinguishing them in the field. Since blade width of both species tends to increase with increasing depth, the differences in width between them are greatest in the region of overlap, a fact which facilitates field discrimination of the two species.

It is likely that the differences in blade width and stand height, noted in emergent intertidal situations, in the lagoon, and along the depth gradient are each an adaptive response (as yet poorly understood) to the particular environment. Larkum (1976) also noted a similar tendency for blade length of *P. australis* to increase with depth.

The vertical distribution pattern of seagrasses is broadly similar to that described for them in Gulf St Vincent (Shepherd & Sprigg 1976). However, differences in their distribution between the two sides of Spencer Gulf are of interest. The abundance of bare sand patches on the western side suggests a less suitable habitat for seagrasses than the opposite shore where seagrass cover is 100%, and an absence of competition between species for space. This may be why there are discrete communities of *P. australis* and *P. sinuosa* bounded by discontinuities of exclusion, and why *H. tasmanica* extends into shallower water on the western shore. A similar distribution pattern to that described for the western shore also occurs further south at Crag Point (Shepherd 1974).

Algal Flora

Five species of Chlorophyta, 18 species of Phaeophyta and 55 species of Rhodophyta (Appendix 1) are recorded here. Additional species are given by Shepherd (1974) for Crag Point, and Johnson⁶ lists the epiphytic flora of seagrasses. The number of species for the region is much less than that recorded on rocky bottom on oceanic coasts (Shepherd & Womersley 1970, 1971, 1976, 1981) and reflects the environmental extremes and the lower habitat diversity in upper Spencer Gulf.

Nearly all of the species in Appendix 1 are widely distributed throughout the southern

Australian (Flindersian) region and are therefore considered as having intermediate warm-cool temperate, biogeographic affinities (Womersley 1959, 1981 a,b). However, two species (*Asparagopsis taxiformis* and *Platysiphonia mutabilis*) occur only westward of the South Australian Gulfs and appear to have warm temperate affinities, and two other species *Sargassum decurrens* and *Hormophysa triquetra* (L.) Kuetzing (the latter recorded by Womersley (1967) but not in this study) are tropical and subtropical in their distributions. In addition, Beanland & Woelkerling (1982) have recorded four more species of tropical affinities on mangrove pneumatophores. Thus there is a small, but distinct tropical, and possibly relict, element in the algal flora.

Fauna

The fauna is dominated by relatively few species, present in considerable abundance, as might be expected for a region of environmental extremes (Copeland & Nixon 1974). The presence of some coelenterates has special interest, *Echinogorgia* sp. and *Scybalium* sp. appear to be endemic in upper Spencer Gulf (Grasshoff 1982). *Virgularia mirabilis*, a cosmopolitan species, is known in South Australia only from this region (Utinomi & Shepherd 1982) and *Telesia multiflora*, a tropical species, is recorded in southern Australia only in mid- and upper Spencer Gulf (Verseveldt 1982). In addition, the ascidian *Sycosia pedunculata* is known in southern Australia only from upper Spencer Gulf and Investigator Strait (Kott 1972, 1975). These last four species, except for *V. mirabilis*, appear to have tropical affinities, suggesting that isolated populations are confined to Gulf waters. In addition, a number of species in other phyla, newly or not yet described are known only from upper Spencer Gulf. They include a bryozoan *Bugula* n.sp., a flatworm *Ancoratheca australensis*, and an opisthobranch *Discodoris* n.sp. Further, the ophiuroid *Amphiura trisacantha* is apparently rare elsewhere (Baker & Devaney 1981).

The benthic environment and the fauna of upper Spencer Gulf differ markedly from those of upper Gulf St Vincent, a region with similar temperature and salinity extremes. The latter region is generally shallow with deeper, silty bottom dominated by a *Pinna*—holothurian assemblage, whereas upper Spencer Gulf has deeper channels, stronger water currents and

generally well-sorted medium to coarse shelly sands. Nowhere in upper Spencer Gulf does *Pinna bicolor* support the rich epizoic fauna described for upper Gulf St Vincent. Of the 32 species considered to be occasional to common in upper Gulf St Vincent by Shepherd & Sprigg (1976), only one echinoderm (*Goniocidaris tubaria*), two molluscs (*Pinna bicolor* and *Malleus meridianus*) and one ascidian (*Polycarpa pedunculata*) occur in comparable abundance in upper Spencer Gulf; the remainder appear to be rare or absent.

Thus on the basis of present knowledge of the fauna of the Gulfs, upper Spencer Gulf is impoverished in terms of overall species richness but relatively rich in species which are either endemic or have tropical affinities.

According to Copeland & Nixon (1974) hypersaline environments are stressed biological systems with fewer species and simpler food webs than less stressed systems. The addition of further stresses e.g. in the form of wastes and other discharges is therefore likely to eliminate more species and even whole food chains. It is critical that such a system should receive very detailed studies of its component parts to determine its capacity to accept additional stresses.

Acknowledgments

The 1973 and 1974 studies were funded by the Petrochemical Consortium of South Australia and the 1980 study by the Department of Marine & Harbors, South Australia.

Mr Forbes Cuming ably skippered the charter vessel in 1973, and Mr K. L. Branden supervised the diving then and on later trips. I am especially grateful to them and to Messrs L. Gray, J. E. Johnson, G. Petersen, G. Ramm, W. Wickes and G. Wright for help in the field and laboratory. Mr J. Heppner assisted with position fixing during 1980. Mr D. Reilly provided accommodation and gave invaluable assistance in many other ways.

I am especially grateful to those who identified organisms. They include Prof. H. B. S. Womersley (algae), Dr J. Versveldt (alcyonacea), Dr P. M. Mather (ascidians), Mr P. E. Bock (hryozoans), Dr A. N. Baker (echinoids and ophiuroids), Dr M. Grasshoff (gorgonians), Mrs J. E. Watson (hydroids), Mr M. G. King (shelled molluscs), Mr R. Burn (opisthobranchs), the late Dr H. Utinomi (pennatulids), Dr S. Prudhoe (platyhelminths), Mr D. Staples (pycnogonids).

Prof. Womersley, Mrs E. Robertson, and Mr Johnson made helpful comments on the manuscript.

References

- BAKER, A. N. & DEVANEY, D. M. (1981) Notes on southern Australian ophiuridea (Echinodermata). *Trans. R. Soc. S. Aust.* **105**, 155-78.
- BAYLY, I. A. E. (1975) Australian estuaries. In H. A. Nix & M. A. Elliott (Eds): "Managing aquatic ecosystems", *Proc. Ecol. Soc. Aust.* **8**, 41-66.
- BEANLAND, W. R. & WOELKERLING, W. J. (1982) Studies on Australian mangrove algae: II. Composition and geographic distribution of communities in Spencer Gulf, South Australia. *Proc. R. Soc. Vict.* **94**, 89-106.
- BUTLER, A. J., OPPERS, A. M., MCKILLUP, S. C. & THOMAS, D. P. (1977) Distribution and sediments of mangrove forests in South Australia. *Trans. R. Soc. S. Aust.* **101**, 35-44.
- & KEOUGH, M. (1981) Distribution of *Pinna bicolor* Gmelin (Mollusca: Bivalvia) in South Australia with observations on recruitment. *Ibid.* **105**, 29-39.
- CHINNOCK, R. J. (1980) The vegetation and flora of Redcliff Point and surrounding areas, South Australia. *J. Adelaide Bot. Gard.* **2**, 329-51.
- CONOVER, W. J. (1971) Practical non-parametric statistics. 462 pp. (Wiley, New York).
- COPELAND, B. J. & NIXON, S. W. (1974) Hypersaline lagoons, pp. 312-30. In H. T. Odum, B. J. Copeland & E. A. McMahon (Eds): "Coastal ecosystems of the United States" (Conservation Foundation; Washington).
- DAVIES, G. R. (1970) Carbonate bank sedimentation, eastern Shark Bay, Western Australia. *Mem. Amer. Ass. Petrol. Geol.* **13**, 85-168.
- DORT, M. S. (1971) Measurement of water movement in reference to benthic algal growth. *Botanica mar.* **14**, 32-5.
- GRASSHOFF, M. (1982) Gorgonians or seafans (Order Gorgonacea), pp. 198-206. In S. A. Shepherd & I. M. Thomas (Eds), "Marine invertebrates of southern Australia" Part I. Handbooks of the fauna and flora of South Australia (Govt Printer; Adelaide).
- HALL, J. R., GOSTIN, V. A. & SARGENT, G. E. (1980) The significance of the submarine geology of upper Spencer Gulf, South Australia, to environmental decision-making. *Search* **11**, 115-6.
- HARTOG, C. DEN (1970) "The Seagrasses of the World." *Verh. K. ned. Akad. Wet. Afd. Natuurk.* ser. 2, **59**, 1-275, 31 plates.
- JOHNSON, J. E. (1981) Hydrological data for upper Spencer Gulf, 1975-1978. *Fish. Res. Pap. Dep. Fish. S. Aust.* No. 3, 1-30.
- KORT, P. (1972) The ascidians of South Australia II. Eastern sector of the Great Australian Bight and Investigator Strait. *Trans. R. Soc. S. Aust.* **96**, 165-96.
- (1975) The ascidians of South Australia III. Northern sector of the Great Australian Bight and additional records. *Ibid.* **99**, 1-20.

- LARKUM, A. W. D. (1976) Ecology of Botany Bay I. Growth of *Posidonia australis* (Brown) Hook. f. in Botany Bay and other Bays of the Sydney basin. *Aust. J. Mar. Freshw. Res.* **27**, 117-27.
- PROVIS, D. G. & RADOK, R. (1979) Sea-level oscillations along the Australian coast. *Ibid.* **30**, 295-301.
- SHEPHERD, S. A. (1974) An underwater survey near Crag Point in upper Spencer Gulf. Dept. Fisheries S.A. Tech. Rept (1), 1-29.
- (1983) Epifauna of megaripples: species' adaptations and population responses to disturbance. *Aust. J. Ecol.* **8**, 3-8.
- & SPRIGG, R. C. (1976) Substrate, sediments and subtidal ecology of Gulf St Vincent and Investigator Strait, pp. 161-74. In C. R. Twidale, M. J. Tyler & B. P. Webb (Eds), "Natural History of the Adelaide Region" (Royal Society of South Australia: Adelaide).
- & WOMERSLEY, H. B. S. (1970) The subtidal ecology of West Island, South Australia. I. Environmental features and the algal ecology. *Trans. R. Soc. S. Aust.* **94**, 105-38.
- & — (1971) Pearson Island Expedition 1969-7. The sub-tidal ecology of benthic algae. *Ibid.* **100**, 177-91.
- & — (1976) The subtidal algal and seagrass ecology of St Francis Island, South Australia. *Ibid.* **95**, 155-67.
- & — (1981) The algal and seagrass ecology of Waterloo Bay, South Australia. *Aquatic Bot.* **11**, 305-71.
- THORSON, G. (1957) Bottom communities (subtidal or shallow shelf). In J. W. Hedgpeth (Ed) *Treatise on marine ecology and palaeoecology* Vol. 1. Ecology, pp. 461-534 (Geol. Soc. Amer.: New York).
- UTINOMI, H. & SHEPHERD, S. A. (1982) Scapens (Order Pennatulacea) pp. 207-19. In S. A. Shepherd & I. M. Thomas (Eds) "Marine Invertebrates of Southern Australia", Part I. Handbooks of the fauna and flora of South Australia. (Govt Printer: Adelaide).
- VERSEVELDT, J. (1982) Soft corals or alcyonarians (Orders Sclerionifera, Telestacea and Alcyonacea). pp. 179-82. In S. A. Shepherd & I. M. Thomas (Eds), "Marine Invertebrates of Southern Australia" Part I. Handbooks of the fauna and flora of South Australia (Govt Printer, Adelaide).
- WEINBERG, S. (1976) Submarine daylight and ecology. *Mar. Biol.* **37**, 291-304.
- WEST, R. J. & LARKUM, A. W. D. (1979) Leaf productivity of the seagrass, *Posidonia australis* in eastern Australian waters. *Aquatic Bot.* **7**, 57-65.
- WESTLAKE, D. F. (1963) Comparisons of plant productivity. *Biol. Rev.* **38**, 385-425.
- WOMERSLEY, H. B. S. (1959) The marine algae of Australia. *Bot. Rev.* **25**, 545-614.
- (1967) A critical survey of the marine algae of southern Australia II. Phaeophyta. *Aust. J. Bot.* **15**, 189-270.
- (1981a) Biogeography of Australasian marine macroalgae. pp. 292-307. In M. N. Clayton & R. J. King (Eds), "Marine Botany: an Australian perspective" (Longman: Melbourne).
- (1981b) Aspects of the distribution and biology of Australian marine macroalgae. pp. 294-306. In A. J. McComb & J. S. Pate (Eds), "Biology of Australian Flora" (University of Western Australia: Perth).

Appendix 1: Algal and seagrass species list for upper Spencer Gulf

Most collections are from deeper water (>10 m) with little data on the shallow water algal flora. Identifications are by H. B. S. Womersley and E. M. Wollaston (Crouanidae, Callithamniaceae, Spongoeloniaceae). Data given are, the transect on which the species was recorded, the depth range (m) and, in brackets, the reference number to the community (see text) in which the species was recorded. 'T.C.' = tributary channel leading to Chinaman Creek.

CHLOROPHYTES

Cladophorales

Cladophora hainesii Harv. 11 m (11)

Caulerpaceae

Caulerpa cuctoides (Turn.) C. Agardh Tr. 2. 8 m (7)

Chlorodesmis buccifera (J. Ag.) Duckett 15 m (11)

Codiaceae

Codium harveyi Silva Tr. 5, 12 m (10), 15 m (11)

PHAEOPHYTES

Ectocarpales

Kueckia spinosa (Kuetz) Kueckel Tr. 2. 11 m (10)

Sphacelariales

Sphacelaria furcigera Kuetzing Tr. 2. 0-1 m (2) epiphytic or *Caulocystis*

Diclyotales

Dictyota dlehotoma (Hudson) Lamouroux Trs 3.5, 10-15 m (3) (5) (10)

Dictyopteris australis (Sund.) Askenasy 15 m (11)

D. muelleri (Sonder) Reinhold Tr. 5, 12 m (6)

Distromium flabellatum Womersley Tr. 5. 8 m (3)

Charidariales

Castagnea sp. T.C. 9 m

Stilophora rhizodes (Turner) J. Agardh Tr. 2. 0-1 m (2)

Nemacystis sp. Tr. 2. 0-1 m (2)

Sporocnallales

Relbottia eriophorum Harv. Trs 2.5, 10-15 m (5) (10) (11)

Nereia australis Harv. Tr. 5, 10 m (3)

Sporocnthus comosus C. Agardh Trs 4.5, 10-15 m (5) (6) (11)

S. radiformis (Turner) C. Agardh 8 m (3)

Dictyosiphonales

Asperococcus hulosus Lamouroux Trs 2-5, 0-18 m (2) (3) (5) (8) (10)

Fucales

Caulocystis cephalanthos (Labill.) Areschoug Trs 2.5, 0-10 m (2) (5)

Sargassum decurrens (R.Br. in Turner) C. Agardh Tr. 5, 10 m (3)

- S. paradoxum* (R.Br. in Turner) H. & H.
Tr. 5, 8 m (3)
S. (Eusargassum) sp. Trs 2-5, 6-18 m (3)
(5) (8) (10)

RHODOPHYTA

Nemaliales—Bonnemaisoniaceae

- Asparagopsis taxiformis* (Delile) Trevisan Tr.
3, 10 m (8)
Bonnemaisonia australis Leving Trs 4,5 10-
12 m (5)

Cryptonemiales—Dumontiaceae

- Dudresnaya australis* J. Agardh Trs 2,4 8-10
m (5)

Corallinaceae

- Jania microrhiza* Lamx Tr. 4, 6 m (3)
Metagoniolithon stelliferum (Lamarck) W.v.B.
Tr. 2, 0-1 m (2)

Gigartinales—Solieriaceae

- Solieria robusta* (Grev.) Kylin Trs 3-5, T.C.
8-18 m (3) (5) (8) (10) (11)

Rhabdoniaceae

- Erythroclonium muelleri* Sonder Trs 4,5, T.C.
9-15 m (10)

- Rhabdonia roccinea* Harvey Trs 2-5, 18 m
(3) (5) (8) (10)

Acrotlyaceae

- Antrocentrus nigrescens* (Hooker & Harvey)
Kraft & Min Thein Tr. 5, 10-15 m (11)

Rhodophyllidaceae

- Craspedocarpus ramentaceus* (C.Ag.) Min
Thein & Womersley 15 m (11)

Hypneaceae

- Hypnea sp.* Tr. 4, 18 m (10)

Gracilariaceae

- Gracilaria sp.* 15 m (11)

Mychodiaceae

- Mychodea aciculare* (J. Agardh) Kraft Trs
3,5, 12-15 m (10)

- M. carnosa* Hooker & Harvey Trs 3-5, 12-
18 m (8) (10)

Rhodymeniales—Rhodymeniaceae

- Botryocladia obovata* (Sonder) Kylin Trs 2-5,
0-18 m (2) (3) (10)

- Coelarthrum muelleri* (Sond.) Borg, Trs 2-5,
T.C. 6-18 m (3) (5) (8) (10) (11)

- Gelosaccion brownii* Harvey 8-15 m (3)
(11)

Champiaceae

- Champia zostericola* (Harv.) Reedman &
Womersley Trs 3-5, T.C. 8-16 m (3) (5)
(8) (10) (11)

Ceramiales—Ceramiceae

Warreniaceae

- Warrentia comosa* (Harvey) Kuetzing Tr. 5,
12 m (10)

Crouaniaceae

- Gartia pinnella* Harvey Trs 2-4, 11-18 (6)
(8) (10)

Antihamniaceae

- Antihamnion divergens* (Sonder) De Toni
Tr. 5, 6-7 m (3) Epiphytic on *Posidonia*

- Macrothamnion secundum* Wollaston Trs 3-
5, 6-15 m (3) (10) (11)

Callithamniaceae

- Callithamnion sp.* Tr. 5, T.C. 8-9 m (5)
Epiphytic on *Chondria*

Spongoecloniaceae

- Haloplegma preissii* Sonder Trs 3,5, 8-18 m
(3) (10)

- Spongoeclonium conspicuum* Sonder Trs 2,5,
8-15 m (3) (5) (10) (11)

- S. sp.* (possibly there are two species) Trs 2,4,
8-12 m (8) (10)

- S. fasciculatum* J. Ag. (?) Trs 2,5, T.C. 9-11
m (5) (10)

Spyridiaceae

- Spyridia filamentosa* (Wulfen) Harvey Tr.
5, 8-10 m (3) (10)

- S. tasmanica* (Kuetz) J.Ag. Trs 3-5, 10-15
m (3) (5) (8) (10) (11)

Delesseriaceae

- Acrosorium uncinatum* (J.Ag.) Kylin Trs
2-4, 8-18 m (5) (8) (10)

Dasyaceae

- Dasya capillaris* H. & H. Trs 4,5, T.C. 8-15
m (10)

- D. extensa* Sonder ex Kuetz T.C. 9-11 m (3)
(10)

- D. sp. 1* T.C. 9 m

- D. sp. 2* T.C. 9 m

- Heterosiphonia gunniana* (Harv.) Reinhold
Trs 2,4,5, 8-10 m (5) (8) (10)

- H. maelleri* (Sond.) De Toni Tr. 5, 10 m (3)

- Heterosiphonia lawrenciana* (Harv.) Parsons
Trs 3,5, 10-18 m (10)

- Lastothulia sp.* Tr. 5, T.C. 8-9 m (3)

Rhodomelaceae Polysiphoniaceae

- Chiracanthia arborea* (Harvey) Falkenberg
Trs 3-5, 8-12 m (3) (5) (8) (10)

- Echinothamnion hystrix* (H. & H.) Kylin
Tr. 5, 10-12 m (3) (5) (10)

- Polysiphonia crassiuscula* Harv. Trs 4,5, 12-
15 m (10) (11)

- P. decipiens* Montagne Tr. 5, 8-12 m (3)
(5) (10)

Lophothaliaceae

- Brongniartella australis* (C.Ag.) Schmitz
Trs 3,4, 6-10 m (3) (8)

- Doxodasya bolbochoete* (Harvey) Falkenberg
Trs 2-5, T.C. 9-18 m (5) (8) (10)

- Lophothallia hormocladus* (J.Ag.) J.Ag. Tr. 2,
11 m (10)

- Lophothalioid sp.* Tr. 4, 15 m (10)

- Micropucea sp.* Tr. 4, T.C. 9-15 m (10) (11)

Pterosiphoniaceae

- Dictymena harveyana* Sonder Trs 3-5, 10-16
m (3) (5) (8) (10)

Placophoriaceae

- Jeannerettia pedicellata* (Harvey) Papenfuss
Trs 3-5, 10, 18 m (3) (5) (8) (10)

Herposiphoniaceae

- Herposiphonia versicolor* (H. & H.) Falken-
berg Trs 3-5, 10-12 m (3) (5) (10)

Polyzoniceae

- Cliftonaea pectinata* Harvey Trs 3,4, 15-18
m (10)

Amansieae

- Protokuetzingia australasica* (Mont.) Falken-
berg Trs 3,5, 8-15 m (3) (5) (10)

Chondriaceae

- Chondria harveyana* J.Ag. Trs 4,5, 8-15 m
(5) (10) (11)

- Laurencia brandenti* Saito & Womersley Trs
3-5, 8-12 m (3) (8) (10)

Sarcomeniaceae

- Platysiphonia mutabilis* (Harvey) Womersley
& Shepley Trs 2,4,5, 8-12 m (3) (5) (8)
(10)

TRACHEOPHYTES—seagrasses

Posidonioideaceae

Amphibolis antarctica (Labill.) Sonder ex Aschers 0–6 m (4)

Heterozostera lasmanica (Mart. ex Aschers) den Hartog Trs 1–5, 7–9 m (5)

Zostera mucronata den Hartog Intertidal (1) (2)

Posidonia australis J. D. Hooker Trs 1–5 m.s.l.—6 m (2) (3)

Appendix 2: A species list of animals in the region of Redcliff during the various surveys

Data given are the transects on which the species was recorded, depth range (m) and, in brackets, the community reference number (see text) in which the species occurs.

T.C. = in Tributary Channel; P = epizoid on *Pinna*.

CNIDARIA

Hydrozoa

Bimeria australis Blackburn 15 m (11)

Clytia hemisphaerica (Linnaeus) 15 m (11)

Eudendrium generale Lendenfeld 10–15 m (9) (10) (11)

Plumularia setacea Ellis 15 m (11)

Anthozoa

Actiniaria: An unidentified red anemone Tr 4, 11 m (10)

Teleostacea: *Telesto multiflora* Laackman Trs 1–5, P. 8–19 m (9) (10)

Acyonacea: *Capnella gaboensis* Verseveldt Trs 2, 4, 11–14 m (9) (10)

Gorgonacea: *Echinogorgia* sp. Trs 1–4, 10–18 m (9) (10)

Euplexaura sp. Trs 2–4, 10–19 m (9) (10)

Pennatulaceae: *Seytallum* sp. 14–18 m (10) (11)

Virgularia gustaviana Herklots

V. mirabilis (Müller) 10–19 m (10) (11)

PLATYHELMINTHES

Ancoratheca australiensis Prudhoe 10 m. (9)

ANNELIDA

Chaetopterus variopedatus (Renier) Tr. 2, T.C. 6–15 m (5) (8) (10) (11)

BRYOZOA (with notes added by Mr P. Rock)

Amathia cf. *brongniartii* Kirkpatrick Trs 2–4, 13–18 m (9) (11)

A. tortuosa Tennyson Woods 14–18 m (9) (11)

Bugula sp.

A biserial species, lacking spines or avicularia, related to *B. neritina* (Linnaeus).

Celleporaria fusa (Busk) 12–17 m (9)

Cornuella cornuta (Busk) 15–18 m (9) (11)

(Distal) angles are less spinose than is usual in *C. cornuta*, *C. taurina* and *C. perforata*. However, due to great variation in this family colonies may be a variant of *C. cornuta*.)

Lanceopora obliqua (MacGillivray) Trs 3, 4, 10–18 m (10) (11)

Menippa roborata (Hinck) 18 m (9) (11)

Triphyllozoon sp. 5–10 m P.

Other epizoid species attached to some of

P. sinuosa Cambridge & Kuo Trs 1–5, 0–6 m (2) (3)

P. angustifolia Cambridge & Kuo Tr. 4, 10 m (3)

Hydrocharitaceae

Halophila ovalis (R.Br.) J. D. Hooker ssp. *australis* (Doty & Stone) den Hartog Trs 1–5, 8–10 m (6).

above species in sandwaves are—

Lichenopora sp.

Scruparia ambigua (D'Orbigny)

Celluria sp.

Mesonina radians (Lamarck)

Crisia acropora Busk

ECHINODERMATA

Crinoidea

Antedon incommoda Bell Trs 2–5, T.C. 4–19 m (8) (9) (10)

Asteroidea

Anthaster valvulatus (Müller & Troschel) Trs 1–5 10–18 m. (9) (10)

Luidia australiae Döderlein Tr 4, 10 m (10)

Patiriella exigua (Lamarck) T.C. 0–1 m (1)

Tosia australis Gray Tr 2, 2–4 m (2) (3)

Ophiuroidea

Amphiplus ochroleuca (Brock) Tr 5, 10 m (10)

Amphipura trisacantha H. L. Clark Tr 4, 10–15 m (10)

A. poecila H. L. Clark Tr 2, 6 m (5)

Ophiomeris semoni (Döderlein) Trs 3, 4, 5, 10–13 m (10)

Ophiocoris opacum H. L. Clark Trs 2, 4, 10–12 m (10)

Ophiothrix (*Placophiothrix*) *spongicola* Simpson Trs 2, 4, 10–14 m (10)

Echinoidea

Goniocladaris tubaria var. *impressa* Koehler Trs 1–5, 4–20 m (5) (8) (9) (10)

Temnopleurus michaelsoni Döderlein 10–12 m (8)

MOLLUSCA

This list is incomplete. Loricata (chitons) are omitted and infaunal species under-represented.

Gastropoda

Bullaria houniea (Hedley) Tr 2, 2–6 m (2) (3) (5)

Hippionyx conicus (Schumacher) T.C. 8 m

Pleurophaca australasia (Perry) T.C. 8 m

Polinices conicus (Lamarck) Tr. 2, T.C. 0–6 m (2) (5)

Thais orbita Gmelin Tr. 5, 6 m (3)

Zoila friendi thersites (Gray) Tr. 4, 3 m (2) (3)

Bivalvia

Brachidontes erosus (Lamarck) T.C. 1 m (2)

B. penetrectus (Verco) Trs 3, 4, P. 12–16 m (10)

Chama ruderalis Lamarck Trs 2–4, 2–19 m (2) (3) (8) (11)

Clree weddingi Cotton Trs 1–4, T.C. 1–17 m (2) (3) (5) (8) (10)

- Chlamys bifrons* Lamarck Trs 3,5, 10–16 m (5) (10)
Cominella chuenae (Reeve) Trs 2,4, T.C. 1–13 m (2) (5) (10)
Corbula verconis Finlay 10 m (10)
Electrona georgiana Quoy & Gaimard Tr. 2, 11 m (10)
Glycymeris flabellatus Tennyson Woods Tr 5, 18 m (10)
Katelysia scalarina Lamarck Tr. 4, T.C. 2–8 m (2)
Lima nimbifer Iredale Trs 4,5, P. 15–18 m (10)
Mallens meridianus Cotton Trs 1–5, T.C. P. 8–20 m (5) (6) (8) (9) (10)
Modiolus inconstans Dunker 0–2 m (2)
Ostrea angasi Sowerby Tr. 2, 10–14 m (10)
Paranassa pauperata (Lamarck) T.C. 2–8 m (2) (3)
Pecten meridionalis (Tate) Trs 2,5, 10–20 m (10)
Phasianotrochus sp. Tr. 2, T.C. 5–8 m (3)
Pinna bicolor Gmelin Trs 1–5, T.C. 0–18 m (2) (3) (4) (5) (6) (8) (10) (11)
Placumen flindersi Cotton & Godfrey Tr. 2, 10 m (5) (10)
Pteryonotus triformis (Reeve) Trs 4,5, 10–12 m (10)
Semele exigua A. Adams Tr. 2, T.C. 0–8 m (2) (3) (5)
Trichomya hirsutus (Lamarck) Trs 2,4,5, P. 1–10 m (2) (3) (5)
Nudibranchia
Armina n. sp. 12–15 m (11)
Ceratosoma brevicaudata Abraham Tr. 5, 18 m (10)
Discodoris n. sp. 15 m (9)
According to R. Burn (pers. comm.) *Armina* sp. is a predator of pennatulids and *Discodoris* sp. of Porifera.
- CRUSTACEA**
Pycnogonida
Pseudopallene cf. *ambigua* Stock 15 m (11)
- CHORDATA**
Ascidiacea (See Kott (1975) for further notes on this fauna)
Ascidia thompsoni Kott Trs 1,2, T.C. 8–17 m (10)
Family Botryllidae nov. gen. nov. spec. T.C. 8 m
Didemnum sp. 12–14 m (11)
Distaplia australiensis Brewin Tr. 3, 16 m (10)
Halocynthia hispida (Herdman) T.C. P. 8–15 m (9)
Herdmania momus (Savigny) T.C. 8 m
Microcosmus nichollsi Kott 4 m (3)
M. squamiger (Michaelsen) T.C. 8 m
M. stolonifera Kott 4 m (3)
Molgula mollis (Herdman) T.C. 10–15 m (11)
Parabotryllus nemorus Kott 14 m (11)
Podoclavella cylindrica (Quoy & Gaimard) On reef near Douglas Bank 15 m
Polycarpa pedunculata (Heller) Trs 1–5, P. 5–20 m (3) (5) (9) (10) (11)
P. papillata (Sluiter) Tr. 4, 6 m (3)
P. tinctor (Quoy & Gaimard) T.C. 8 m
Pyura australis (Quoy & Gaimard) On reef near Douglas Bank, 15 m
P. irregularis (Herdman) Trs 2,4, P., 2–6 m (2) (3)
P. scoresbiensis Kott Trs 1,3, T.C. 8–17 m (8) (10)
P. vittata (Stimpson) Tr. 2, P., 2 m (2)
Sycozoa pedunculata (Quoy & Gaimard) Trs 1–4, 14–20 m (11)

APPENDIX 3. Fish recorded in the Sponge—*Telesto* community on rocky bottom, with notes on abundance.

Scientific and Common Names	Occurrence
<i>Chelmonops truncatus</i> (Kner) Coral Fish	Occasional
<i>Chrysophrys unicolor</i> Quoy & Gaimard Snapper (juvenile)	Very common in large schools
<i>Helotes sexlineatus</i> (Quoy & Gaimard) Striped Perch	Occasional
<i>Orectolobus ornatus halei</i> (Whitley) Carpet Shark: Gulf Wobbegong	Rare
<i>Parapercis haackei</i> (Steindachner) Grub fish—wavy	A territorial species living in burrows; common over entire area.
<i>Parequula melbournensis</i> (Castelna) Silver belly low fin	Common—in small groups.
<i>Pentaceropsis recurvirostris</i> (Richardson) Boar fish—long-snouted	Rare
<i>Pseudorhombus jenynsii</i> (Bleeker) Flounder small-toothed	Rare; in sandy areas.
<i>Trachichthys australis</i> Shaw & Nodder Roughy	Rare
<i>Trygonorrhina fasciata guenerius</i> Whitley Southern Fiddler	Rare
<i>Usacaranx georgianus</i> (Cuvier & Valenciennes) Trevally	Very common. Large schools.

REDEFINITION OF THE LITORIA LATOPALMATA SPECIES GROUP (ANURA: HYLIDAE)

BY MARGARET DAVIES, ANGUS A. MARTIN & G.F. WATSON

Summary

The *Litoria latopalmata* species group is composed of four terrestrial species characterized by unwebbed fingers, moderately webbed toes, poorly expanded finger and toe discs and variously developed lateral head stripes. The calls of all species are complex and consist of both short and long notes that are quite distinctive. Larvae of each species are very similar and of typical *Litoria* lentic form with 2/3 tooth rows. Osteology is conservative and differences between species are slight. Morphological characters separating species include rugosity of the skin, size of finger and toe discs, development of head and tibial stripes and differential thigh markings. Species included in the group are *Litoria latopalmata* Günther, *L. inermis* (Peters), *L. tornieri* (Noeden) and *L. pallida* sp. nov. The species group has been redefined in the light of morphological, call, larval and osteological data presented.

REDEFINITION OF THE *LITORIA LATOPALMATA* SPECIES GROUP (ANURA: HYLIDAE)

by MARGARET DAVIES,* ANGUS A. MARTIN† & G. F. WATSON†

Summary

DAVIES, M., MARTIN, A. A. & WATSON, G. F. (1983) Redefinition of the *Litoria latopalmata* species group (Anura: Hylidae). *Trans. R. Soc. S. Aust.* **107**(2), 87-108, 31 May, 1983.

The *Litoria latopalmata* species group is composed of four terrestrial species characterized by unwebbed fingers, moderately webbed toes, poorly expanded finger and toe discs and variously developed lateral head stripes. The calls of all species are complex and consist of both short and long notes that are quite distinctive. Larvae of each species are very similar and of typical *Litoria* lentic form with 2½ tooth rows. Osteology is conservative and differences between species are slight. Morphological characters separating species include rugosity of the skin, size of finger and toe discs, development of head and tibial stripes and differential thigh markings. Species included in the group are *Litoria latopalmata* Günther, *L. inermis* (Peters), *L. tornieri* (Nieden) and *L. pullida* sp. nov. The species group has been redefined in the light of morphological, call, larval and osteological data presented.

KEY WORDS: Anura, Hylidae, *Litoria*, morphology, osteology, larvae, mating calls, distribution.

Introduction

The Australopapuan hylid frog genus *Litoria* Tschudi is a heterogeneous assemblage of species including frogs that can be described as 'tree frogs', with greatly expanded finger and toe discs and extensive webbing, as well as terrestrial species with unexpanded discs, long limbs and poor webbing. These latter species were called 'ground hylids' by Moore (1961).

Amongst the ground hylids is a homogeneous collection of species referred to as the *Litoria latopalmata* species group by Tyler and Davies (1978). The group includes *L. latopalmata* Günther, *L. inermis* (Peters) and *L. tornieri* (Nieden). The former two species have been recorded as having an extremely wide geographic range across north and east Australia (Moore 1961, Tyler 1968b, Straughan 1969, Cogger 1979, Barker and Grigg 1977). Tyler (1977) reported the occurrence of *L. latopalmata* in South Australia. Many of these authors have suggested that specimens referred to *L. latopalmata* may represent more than one species.

Here we redefine the described species and describe one new species referable to the *L. latopalmata* species group, based on our studies of comparative morphology, osteology and breeding biology.

Materials and Methods

The specimens reported here are deposited in institutions abbreviated in the text as follows: AM, Australian Museum, Sydney; AMNH, American Museum of Natural History, New York; BMNH, British Museum (Natural History), London; KU, University of Kansas, Museum of Natural History, Kansas; NTM, Northern Territory Museum, Darwin; QM, Queensland Museum, Brisbane; SAM, South Australian Museum, Adelaide; WAM, Western Australian Museum, Perth; QPN, Queensland National Parks and Wildlife Service; RMNH, Rijksmuseum van Natuurlijke Historie, Leiden; UAZ, University of Adelaide, Department of Zoology. UAZ specimens are all cleared and stained skeletal preparations.

Methods of measurement follow Tyler (1968a) and osteological descriptions follow Trueb (1979). Tadpoles were fixed in Tyler's (1962) fixative and staged according to Gosner (1960). Osteological specimens were cleared and stained for bone after Davis & Gore (1947). Measurements were made using dial calipers or an eyepiece micrometer.

Measurements taken of adults were: snout to vent length (S-V); tibia length (TL); head length (HL); head width (HW); eye to naris distance (E-N); internarial span (IN); eye diameter (E); tympanum diameter (T). The following ratios were calculated: TL/S-V; HL/HW; HL/S-V; E-N/IN. Total length (tl) and body lengths (bl) of larvae also were re-

* Department of Zoology, University of Adelaide, Box 498, GPO, Adelaide, S. Aust., 5001.

† Department of Zoology, University of Melbourne, Parkville, Vic. 3052.

corded. Where appropriate, means \pm S.D. are given.

Calls were recorded using a Sony TC 510-2, Uher 4000 or Sharp 4D492 tape recorder with dynamic microphones. Wet-bulb air temperatures were measured with a Schultheis quick-reading thermometer close to the calling sites of males. Calls were analysed by means of a sound spectrograph (Kay Model 6061-B Sona-Graph) with the overall response curve maintained in the FL-1 position. Temporal characteristics of calls were determined from wide-band (300 Hz bandpass) and spectral characteristics from narrow-band (45 Hz bandpass) spectrograms. Two or three examples of each kind of call note given by each male were analysed and mean values were calculated.

Calls of all of the species examined share the same general structure. Two distinct kinds of note are produced; these we have designated 'long calls' and 'short calls'. Each male typically emits call notes in long sequences, usually commencing with short calls and then switching to the production of long calls. Occasionally there are also notes which appear transitional between short and long calls, but we have not attempted to analyse such transitional notes. For each species we present

analyses of what we consider to be typical short and long call notes. Most calls are well-tuned, with harmonic bands across a fairly wide frequency range. We have taken the dominant frequency as the band or bands containing the most energy. Although our call samples are clearly inadequate, the data are included because they assist specific diagnoses.

The following abbreviations are used in locality data: S.F., State Forest, N.P., National Park, Ck, Creek, Hstd, Homestead.

Litoria latopalmata Günther

FIGS 1-7

Litoria latopalmata Günther 1867, *Ann. Mag. nat. Hist.* ser. 3, 20:55

Hyla latopalmata: Boulenger 1882, p. 414; Nieden 1923, p. 227

Hyla palmata: Slevin 1955 (lapsus pro *Hyla latopalmata*) p. 383

Litoria latopalmata: Tyler 1971 (*partim*), p. 353

Definition: A moderately small, ground-dwelling species (females 36-42 mm, males 29-39 mm) characterised by unwebbed fingers with slightly expanded discs, first finger slightly longer than second, moderately long hind

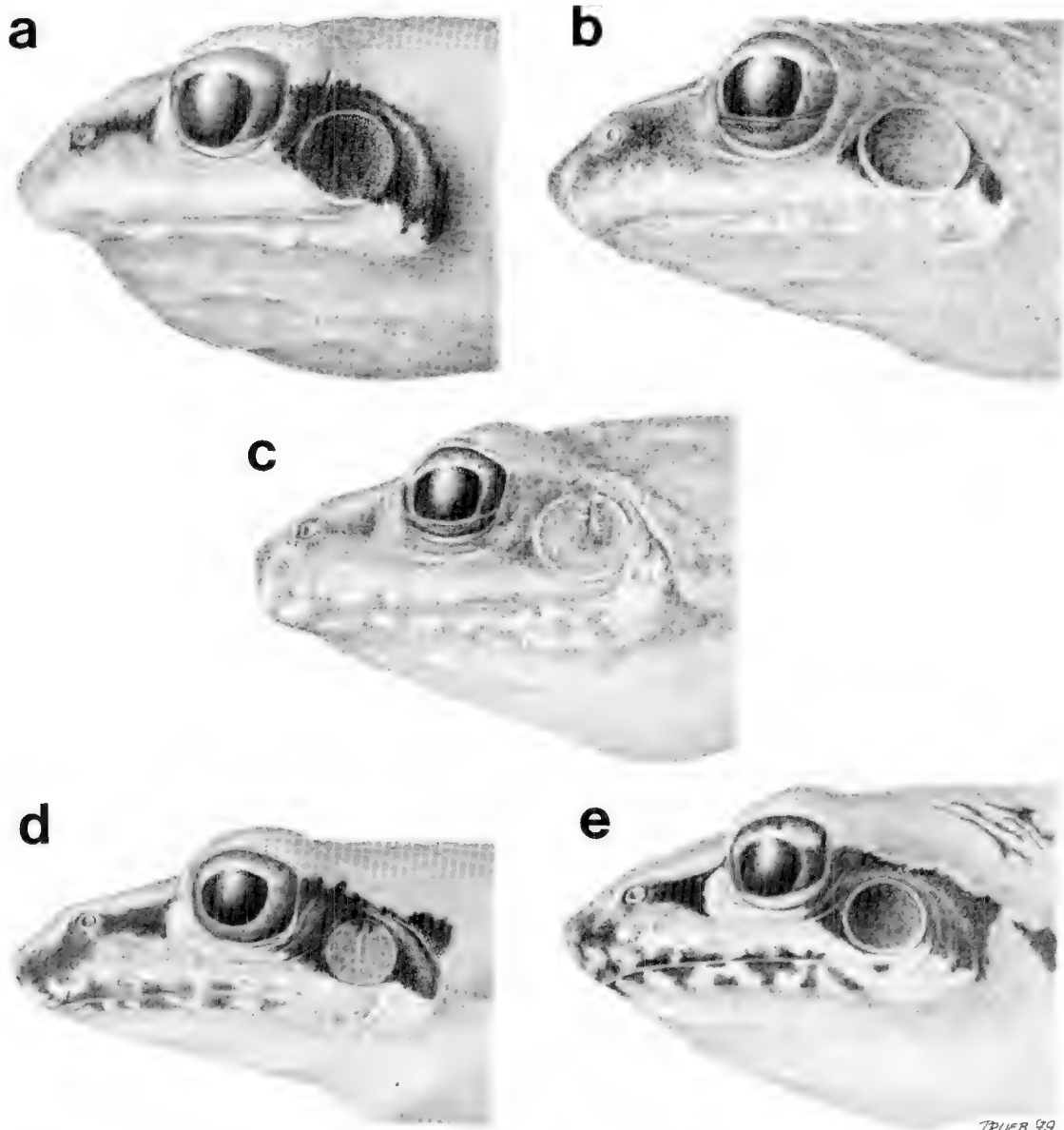


Fig. 1. *Litoria latopalmata*, in life (Watagan, S. F., N.S.W.).

limbs (TL/S-V 0.57–0.75), well developed lateral headstripe with white preocular bar, grey or brown dorsum, occasionally mottled. *Redescription*: based on SAM R19717, a mature male collected north of Maryborough, Qld by K. R. McDonald on 10.xii.1977.

Head broader than long (HL/HW 1.23). Head length more than 1/3 snout to vent length (HL/S-V 0.40). Snout prominent,

projecting in profile (Fig. 1), sharp when viewed from above and very gently rounded in profile. Nostrils more lateral than superior, their distance from end of snout about 2/3 that from eye. Distance between eye and naris less than internarial span (E-N/IN 0.97). Canthus rostralis well defined and straight, its nature accentuated by dark rostral stripe. Eye moderately conspicuous, its dia-



TRUEB 99

Fig. 2. Lateral view of the heads of a, *Litoria pallida* (SAM R19539), b, *L. inermis* (from Qld, SAM R19558), c, *L. inermis* (from W. Aust.), d, *L. tornieri* (SAM R19572) and e, *L. latopalmata* (SAM R19682).

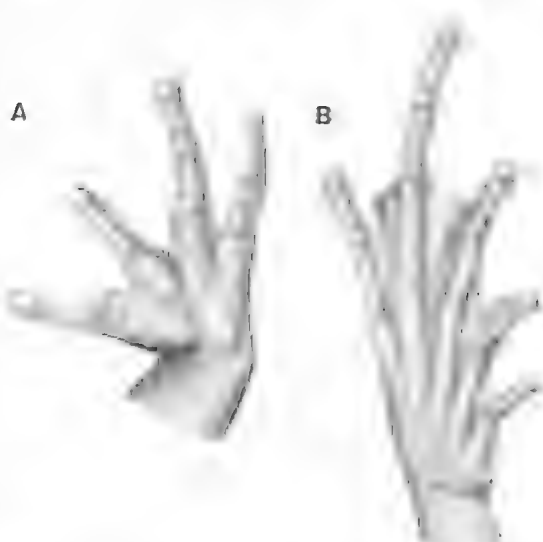


Fig. 3. A, Palmar view of hand and B, plantar view of foot of *Litoria latopalmata* (SAM R19539).

meter about $1/3$ longer than eye to naris distance. Tympanum completely visible, its diameter $\frac{2}{3}$ eye diameter (Fig. 2).

Vomerine teeth on short oval projections at 45° to choanae. Tongue broadly oval. Fingers long and slender, slightly fringed (Fig. 3A); in order of length $3 > 4 > 1 > 2$. No webbing between fingers. Terminal discs slightly expanded just extending laterally beyond the fringes of the penultimate phalanx. Subarticular and palmar tubercles prominent. Small supernumerary tubercles present.

Hind limbs long (TL/S-V 0.65). Toes in order of length $4 > 3 > 5 > 2 > 1$ (Fig. 3B). Webbing reaches midpoint of penultimate phalanx on toe 5 and to subarticular tubercles at base of antepenultimate phalanx on toe 4. Subarticular tubercles prominent. Well developed supernumerary tubercles on metatarsals 3 and 4. Small oval inner and tiny, round, outer metatarsal tubercles.

Dorsum smooth, abdomen, pectoral region ventral and posterior thighs coarsely granular. Submandibular area smooth. Well developed tarsal and supratympanic folds.

Dorsum grey; conspicuous lateral headstripe from nostril to eye, interrupted by cream preocular bar, extending behind the eye over and through the tympanum to the insertion of the forearm. Thin white line extends from below eye to end of mandibular region. Disrupted dark patches extend to flanks. Mandibular margin variegated with dark and light



Fig. 4. Backs of thighs showing pigment reticulations: a, *Litoria pullida*, b, *L. tornieri*, c, *L. latopalmata*, d, *L. inermis*.

patches which extend around upper jaw, faint dark patch present on wrist.

Backs of thighs pale yellow with discrete patches of brown pigmentation (Fig. 4). Thin disrupted dark stripe along anterior edge of tibia and tarsus, and on plantar surface of tarsus and foot.

Gular region lightly suffused with pigment. Brown bilobed nuptial pad present.

Material examined: BMNH 1947.2.24 (syntype) Port Denison (Bowen) Qld. Queensland: SAM R19711-29 N of Maryborough; SAM R19694-19710, Conondale Ra., QPN N28404, N28434, N28454-63, N28472 Ambathala Nature Reserve; SAM R19671-81, Bellthorpe, S. F., Conondale Ra., SAM R19683-93, Eungella N.P.; QM J31364,

J31370, Conondale Ra.; QM J31374-5, below Boombana N.P.; Mt Nebo Rd; QM J35796, Ferguson, 6 km N of Maryborough; UAZ A66, Eungella N.P.; UAZ A67-8, A522, Bellthorpe S. F., Conondale Ra.; UAZ A521, Ambathala Nature Reserve; N.S.W.; SAM R12200-2, Ulong; SAM R19670, Penshurst; SAM R19669, Sherwood S. F.; SAM R12196-9, Camden; SAM R12194-5, Tumby Umbi; QM J31376-8, Back Creek Rd off Tenterfield-Bonshaw Rd; S.A.; SAM R15840, Moonbba.

Variation

Head broader than long (HL/HW 1.24 ± 0.05 , 1.10–1.40); head length greater than 1/3 snout to vent length (HL/S-V 0.39 ± 0.02 , 0.34–0.42). Distance between eye and naris usually less than internarial span (0.94 ± 0.10 , 0.77–1.38).

Hind limbs consistently long (TL/S-V 0.64 ± 0.03 , 0.56–0.75). Dorsum grey or mottled. Tibial stripe interrupted in many specimens, but entire in others.

Osteology

Skull moderately well ossified with well ossified neurocranium. Sphenethmoid well ossified extending between nasals dorsally almost to their anterior extremities, ventrally extending anteriorly to dentigerous processes of prevomers. Nasals overlying sphenethmoid along their medial edges (Fig. 5A). Preotic and exoccipital fused. Exoccipital entire. Crista parotica well developed, moderately long and stocky. Otic ramus of squamosal

expanded posteriorly, just articulating with distal edges of crista parotica.

Frontoparietal fontanelle extensive, extending anteriorly to level of palatines, posteriorly to suture of frontoparietal and exoccipital region. Orbital edges of frontoparietals straight. Nasals moderately large, maxillary processes acuminate, not articulating with well developed preorbital processes of pars facialis of maxillary.

Palatines moderately long, expanded distally, tapering more medially to overlie sphenethmoid. Parasphenoid robust, cultriform process subacuminate, long, almost reaching to level of palatines. Alae broad, at right angles to cultriform process, expanded distally, and overlapped by medial arm of pterygoid (Fig. 5B).

Pterygoids moderately robust, anterior arm in short contact with palatal shelf of maxillary. No obvious pterygoid process of palatal shelf. Medial arm well developed, rounded terminally. Quadratojugal slender and fully articulated. Squamosal moderately robust; zygomatic ramus acuminate, slightly shorter than otic ramus. Maxillary and premaxillary dentate.

Pars facialis moderately shallow, well developed preorbital process. Alary processes of premaxillaries elongate laterally and curved posterolaterally. Palatine processes of premaxillaries well developed, not abutting medially. Prevomers slightly reduced medially, with short dentigerous process slightly angled to midline. Bony columella present.

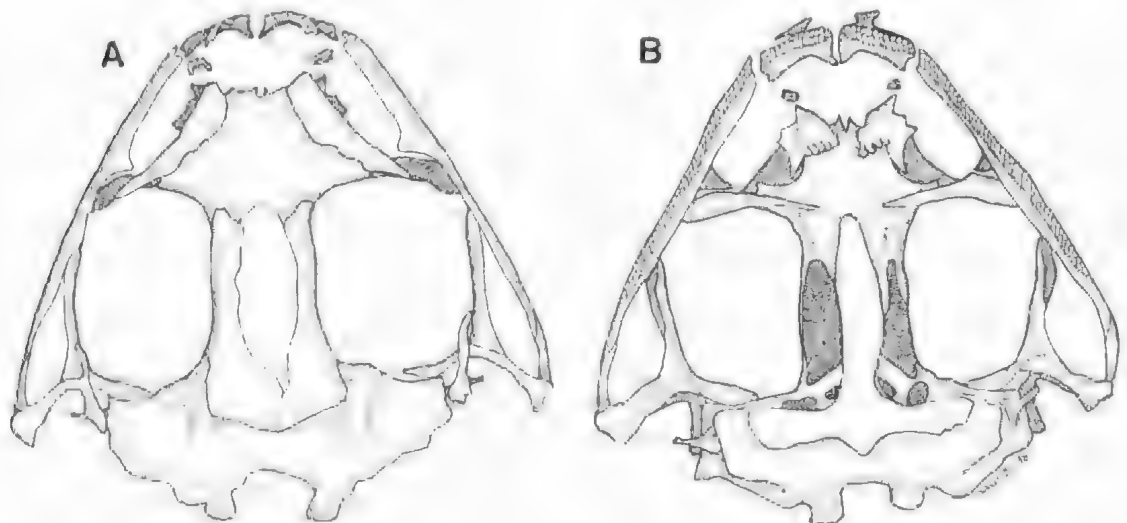


Fig. 5: A, Dorsal and B, ventral views of skull of *Litoria latopalmata* (UAZ A522).

TABLE 1. Physical characteristics of calls of males of the *L. latopalmata* species group. Mean values are given with ranges in parentheses. PRR = pulse repetition rate. Details of localities are: 1, 30 km W Coonabarabran, NSW, 20.x.1964; 2, Mitchell Plateau, W. Aust., 27.i.1978; 3, Coen Airport, Qld, 7.ii.1979; 4, Lakefield N.P., Qld, 25.ii.1981; 5, Gulungul Ck Crossing, Arnhem Highway, N.T., 1.ii.1979; 6, Birndu, N.T., 30.xi.1978.

Species, locality and date	N	Short Call				Long Call				
		Duration msec	No. of pulses	PRR pulses/sec	Dom. freq. Hz	Duration msec	No. of pulses	PRR pulses/sec	Dom. freq. Hz	Wet bulb temp
<i>L. latopalmata</i> 1	1	52.5 (45-60)	7 (6-8)	114 (111-117)	2900	88.3 (85-90)	12 (11-13)	124.3 (118-133)	2900	9.5
<i>L. inermis</i>	2	37	7.5 (7-8)	175.5 (162-189)	3000	175 (165-185)	39.7 (37-41)	221 (216-229)	3300	24.0
	3	27.3 (27-28)	7	219.3 (214-222)	4250	66.7 (60-75)	17.7 (16-20)	249.7 (246-253)	3850	24.8
	4	36 (35-37)	8	194.3 (189-200)	4300	105 (100-110)	27.7 (27-29)	254.3 (248-260)	4100	25.4
<i>L. tornieri</i>	5	68.3 (65-70)	11.3 (10-12)	150.8 (138-157)	2000	128.3 (115-140)	23.8 (22-25)	178.2 (171-183)	1850	25.0- 26.0
	6	59 (57-60)	10	152.7 (150-158)	1950	198.3 (195-200)	35	176 (171-179)	1950	27.2
<i>L. pallida</i>	5	30	5.5 (5-6)	150 (133-167)	1500	337.5 (330-345)	63.5 (61-66)	185 (182-188)	1500, 3300, 4000	25.0
	3	22.5 (20-25)	3.5 (3-4)	110 (100-120)	1450, 4150	455 (450-460)	81.3 (78-84)	176.3 (171-180)	3400 4150	25.8

Pectoral girdle arciferal and robust. Omosternum and xiphisternum present. Clavicles moderately slender, slightly shorter than scapula and closely applied medially. Coracoids moderately separated. Suprascapula about 2/3 ossified.

Eight procoelous, nonimbricate, presacral vertebrae. Medial dorsal ossification incomplete on vertebrae I, II, III and IV. Relative widths of transverse processes: III > IV > V II > sacrum = VI > VII > VIII. Sacral diapophyses poorly to moderately expanded; ilia extend anteriorly beyond expansion. Bicondylar sacrococcygeal articulation. Well developed crest extending 1/2 length of urostyle.

Phalangeal formula of hand 3,3,4,4; well developed bony prepollex. Phalangeal formula of foot 3,3,4,5,4; well developed bony prehallux. Terminal phalanges claw shaped.

Variation

Prevomarine teeth are sometimes horizontally oriented, rather than slightly angled to midline. The maxillary processes of the nasals

occasionally articulate with the periorbital processes of the pars facialis of the maxillaries.

Breeding Biology

Call: Physical characteristics of the calls of a New South Wales male are shown in Table 1 and audiospectrograms of short and long calls in Fig. 6. This species shows the least differentiation between short and long calls; both are well-tuned notes. Caution must be used in comparing these calls with those of the other species because of the much lower recording temperature.

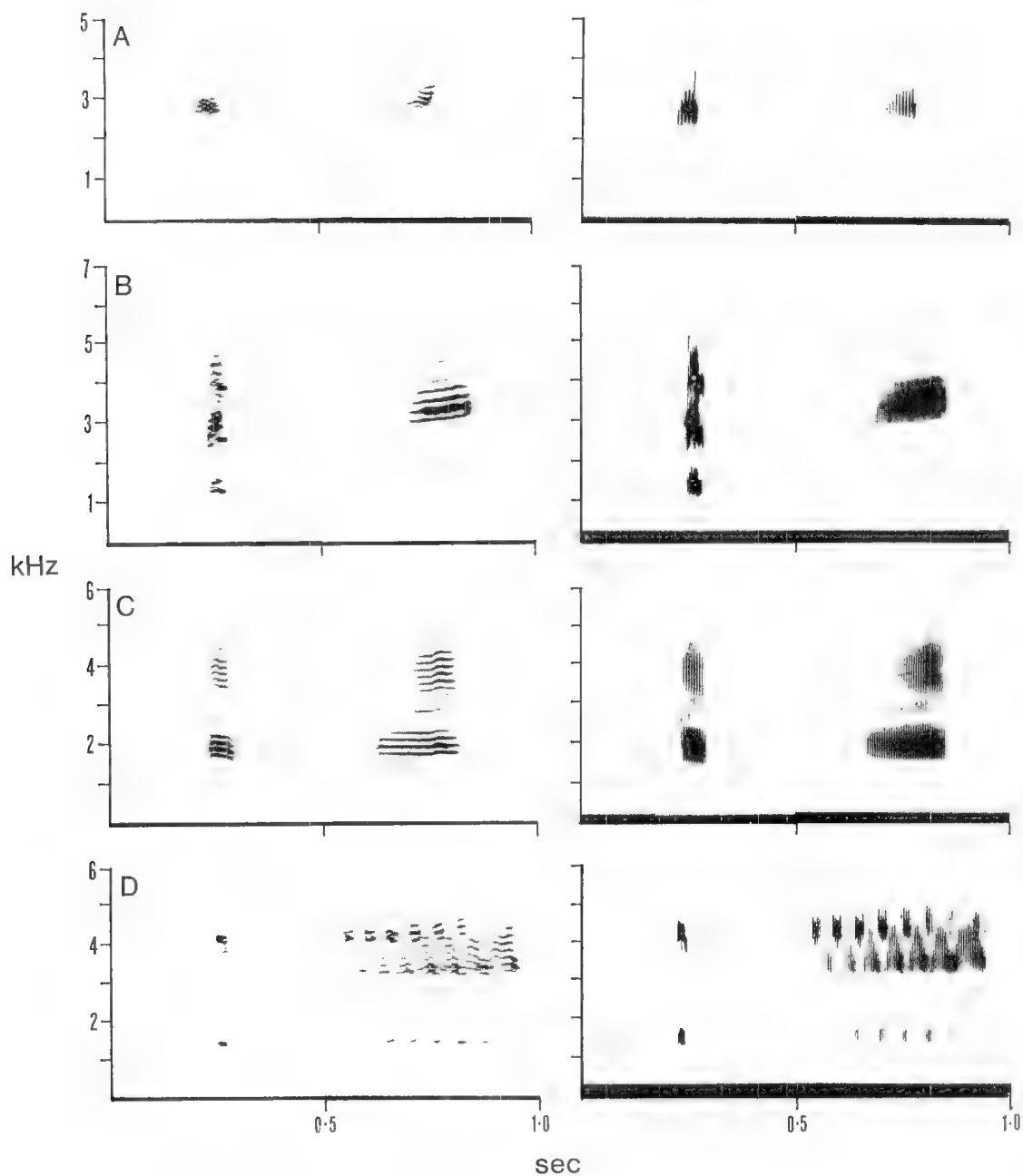
Early development: Unknown.

Distribution

This species is confined to eastern Australia (Fig. 7). The type locality is Port Denison (Bowen) Qld and the species extends south through Queensland to northern N.S.W. A specimen was collected at Gidgealpa Waterhole in South Australia in 1976 (Tyler, 1977).

Litoria latopalmata is an open forest species breeding in temporary, summer rain-filled

Fig. 6. Audiospectrograms of calls of males of the *Litoria latopalmata* species group. In each case the traces are, left to right: short call, 45 Hz bandpass; long call, 45 Hz bandpass; short call, 300 Hz bandpass; long call, 300 Hz bandpass. A, *L. latopalmata*, 3 km W of Coonabarabran, N.S.W., wet bulb 9.5°C; B, *L. inermis*, Mitchell Plateau, W.A., wet bulb 24.0°C; C, *L. tornieri*, Birndu, N.T., wet bulb 27.2°C; D, *L. pallida*, Coen Airport, N.Q., wet bulb 25.8°C.



* Spots and diagonal lines on 300 Hz bandpass of *C. L. tornieri* are trace damage artifacts.



Fig. 7. Distribution of *Litoria latopalmata* and *L. tornieri* in Australia. Open symbols indicate literature records and closed symbols specimens examined in this study. Stars indicate type localities. *L. latopalmata* records = circles, *L. tornieri* records = triangles.

pools. It is sympatric with *L. inermis* at many localities.

Comparison with other species

Litoria latopalmata can be distinguished from all terrestrial congeners, other than members of the *Litoria aurea*, *L. freycineti* and *L. latopalmata* species groups, by its poorly expanded finger discs. The members of the *L. aurea* group differ in gross habitus and size and the *L. freycineti* group have relatively longer hind limbs. *L. latopalmata* can be delineated from other members of its species group in the following ways. From *L. inermis*, *L. latopalmata* can be distinguished by its relatively smooth dorsum and well defined canthal stripe and from *L. tornieri*, by its longer hind limbs ($TL/S-V$ 0.64 ± 0.03 compared with 0.57 ± 0.04), slightly greater webbing between toes four and five and by the slight expansion of its finger and toe discs beyond the edges of the penultimate phalanges. *L. latopalmata* is distinguished from *L. pallida* by its larger size (28–37 mm male, 36–42 mm female, compared with 27–34 mm male, 31–37 mm female) and slightly expanded discs. *Litoria latopalmata* shows the least differentiation between long and short calls, with long calls being shorter than in all other species.

Litoria inermis (Peters)

FIGS 2, 4, 6, 8–13

Chiroleptes inermis Peters, 1867, *Mhrr. dt. Akad. Wiss. Berlin* 1867: 30

Phractops inermis: Nieden 1923, p. 524

Cyclorana inermis: Parker 1940, p. 17

Hyla latopalmata: Tyler 1968b (*partim*) p. 719

Hyla inermis: Straughan 1969, p. 208

Litoria inermis: Tyler 1971, p. 353

Definition: A small, ground-dwelling species (females 30–37 mm; males 24–33 mm) characterised by unwebbed fingers; poorly expanded terminal discs, first finger slightly longer than second, moderately long hind limbs ($TL/S-V$ 0.59 ± 0.04 , $0.52–0.68$); indistinct headstripe; mottled tubercular dorsum. **Redescription of syntype** RMNH 1888. Rockhampton, Qld.

Head longer than broad (HL/HW 1.18). Head length more than 1/3 snout to vent length ($HL/S-V$ 0.37). Snout prominent, projecting in profile (Fig. 8), slightly rounded when viewed from above and in profile. Nostrils slightly more lateral than superior, their distance from end of snout less than twice that to eye. Distance between eye and naris less than internarial span ($E-N/IN$ 0.83). Canthus rostralis very slightly defined and straight. Eye relatively small and incon-

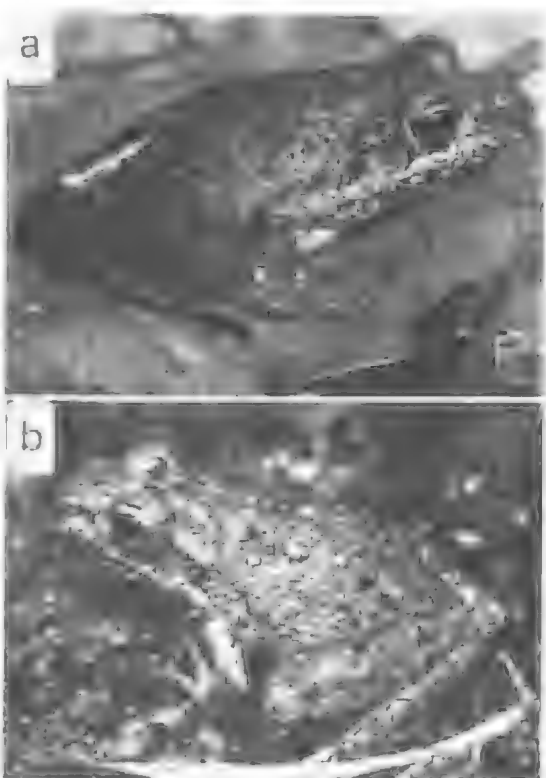


Fig. 8. *Litoria inermis* in life: a, Fossilbrook Ck, Qld and b, Borooloola, N.T.

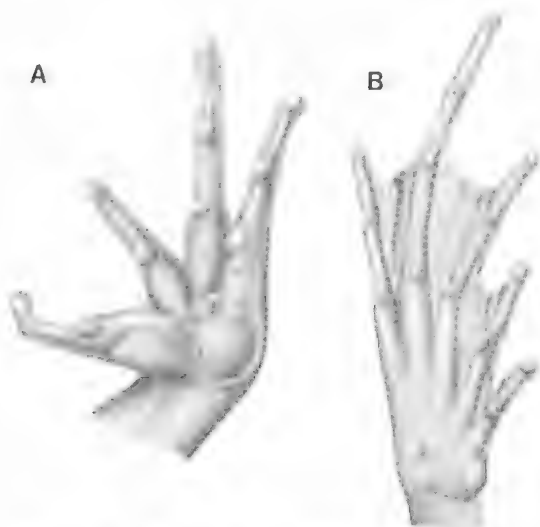


Fig. 9. A, Palmar view of hand and B, plantar view of foot of *Litoria inermis* (SAM R19558).

spicuous, its diameter greater than eye to naris distance. Tympanum completely visible, its diameter about $2/3$ eye diameter (Fig. 2).

Vomerine teeth on short oval elevations at 45° to midline between choanae. Tongue broadly oval. Fingers long and slender, unwebbed with well developed fringes. In order of length $3 > 1 > 4 > 2$ (Fig. 9A). Terminal discs poorly developed and not extending laterally beyond fringes. Subarticular and palmar tubercles prominent. Supernumerary tubercles on metacarpals not well developed.

Hind limbs long (TL/S-V 0.62). Toes in order of length $4 > 3 > 5 > 2 > 1$ (Fig. 9B). Webbing not reaching midpoint of penultimate phalanx on toe 5 and to subarticular tubercle of antepenultimate phalanx on toe 4. Subarticular tubercles prominent. Small oval inner and rounded outer metatarsal tubercles. Dorsum weakly tubercular; abdomen and back of thighs finely granular; submandibular area smooth. Moderately developed tarsal fold and weakly developed supratympanic fold.

Colour in preservative: dorsum brownish with darker brown mottling. Very poorly developed indistinct lateral headstripe only visible behind eye through tympanum to level of forearm. Well developed cream mottled patch at angle of jaw; edge of mouth surrounded by white variegations with dark pigment granules. Hind portion of thighs reticulated brown on grey, ventral surface discoloured brown.

Material examined: Two syntypes: RMNH 1888, Rockhampton, Qld; AMNH 23582, Bowen, Qld and 184 additional specimens.

Queensland: SAM R19562–70, Fossilbrook Ck; SAM R19559–61, N of Maryborough; SAM R19557, Cape Hillsborough; SAM R19556, Mourangee Stn; SAM R12118–23, Leggitts Lagoon nr Cooktown; SAM R11033–4, Cooktown; QPN N32440–1, Coen; QPN N32341, 32347, Coen Airport; QPN N32494, Silver Plains Hstd; SAM R19571 (16) Eight Mile Ck floodplain, Conjuboy Stn; QM J27188–9, approx. 50 km S Winton; QM J27631, J32522, J32524, J32526, Alice R., 7 km S, 23 km W Townsville; QM J27688, J32536–8, J32540–2, Black R., "1 km D, 3 km E Yabulu; QM J35768, Ferguson Quarry 'via' Maryborough; QM J35770, Burgowan Minesite No. 13, E of Howard; QM J35771, Ferguson, 6 km N Maryborough; UAZ A237, Mourangee Stn, Eudungalba; UAZ A527 McIlwraith Ra.; UAZ A528, N of Maryborough; QM J41012, Lakefield N.P., at Lakefield Hst; QM J41011, Coen Airport.

Northern Territory: SAM R23285–300, SAM R23343–52, SAM R23312–25, R23352, R23284, Jabiru Airstrip; SAM R23303–10, Ja Ja Borrow Pit at Pan Continental Camp entrance; SAM R23327–9, McArthur R. on Bridge to McArthur River Stn; SAM R23302, Cannon Hill; SAM R23301, Surprise Ck, 40 km N McArthur R. Stn; SAM R9835, Berry Springs; SAM R9105 145 km N Mainoru; SAM R23283, 50 m N Retention Pond No. 2 Djalkmarra Ck; SAM R23338–42, Katherine R., 7 km W Katherine Gorge N.P., SAM R23326, 14 km N Katherine; SAM R23330–3, 13 km N Katherine; SAM R23311, 6.4 km N Katherine; SAM R23334–7, 4 km N Katherine; UAZ A616, 100 m E Jim Jim turnoff, Arnhem Highway; UAZ A617, Jabiru Airstrip; UAZ A618, Jabiru East turnoff, Arnhem Highway; NTM R10093–7, 4 km N Katherine.

Western Australia: UAZ A241–2, A529, Mitchell Plateau; UAZ A530, Parry Ck/Kununurra Rd; WAM R81873–83, Granite Ck, 16 km NE Lake Argyle Village; WAM R81884–88, Kununurra; WAM R81890–99, Mitchell Plateau; WAM R81889, Mitchell Plateau campsite; WAM R81901–2, Ivanhoe Crossing; WAM R81900, Hidden Valley, Kununurra; KU192460–4, Mitchell Plateau; KU192465, Four Mile Creek, 32 km ESE Kununurra.

Variation

Small frog (males 24–33 mm, females 30–37 mm S-V). Head longer than broad (HL/HW 1.26 ± 0.062 , 1.11 – 1.40). Head length $1/3$ – $1/2$ snout to vent length (HL/S-V 0.39 ± 0.017 , 0.34 – 0.43). Hind limbs long (TL/S-V 0.59 ± 0.044 , 0.51 – 0.68). E-N/IN highly variable (0.91 ± 0.098 , 0.73 – 1.21).

The syntype is discoloured and soft. Freshly preserved specimens differ from it in the presence of supernumerary tubercles on all metacarpals, and in having coarsely to poorly tubercular grey dorsum mottled with black and brown patches. The lateral headstripe is always poorly developed, sometimes evident anteriorly to the eye and nostrils and through and above the tympanum posteriorly. The ventral surface is pale cream. Back of thighs darkly pigmented with small patches of pale ground colour (Fig. 4).

Osteology

Skull relatively fragile with moderately ossified neurocranium. Sphenethmoid moderately ossified extending between nasals for about $\frac{1}{2}$ of their length dorsally; ventrally sphenethmoid not extending between prevomers. Nasals not overlying sphenethmoid. Prootic and exoccipital fused. Exoccipital not fused dorsomedially or ventromedially. Crista parotica moderately well developed, short and stocky, not articulating laterally with poorly expanded otic ramus of squamosal (Fig. 10A). Frontoparietal fontanelle extensive, rectangular extending anteriorly for about $\frac{1}{2}$ orbit. Posterior margin of fontanelle not delineated because of lack of medial ossification of exoccipital. Orbital edges of frontoparietal straight.

Nasals moderately large. Maxillary process of nasals moderately sharp, not articulating with well developed preorbital process of pars

facialis of maxillary. Palatines moderately long, broad laterally, slender and acuminate medially, overlying sphenethmoid. Parasphenoid robust; broad cultriform process reaching almost to level of palatines; alae long, moderately broad, just overlapped by medial arm of pterygoid.

Pterygoid moderately well developed with anterior arm making short contact with palatal shelf of maxillary (Fig. 10B). No pterygoid process. Medial arm of pterygoid moderately long, not in bony contact with prootic region. Quadratojugal slender and fully articulated. Squamosal moderately robust. Otic ramus slightly longer than zygomatic ramus. Maxillary and premaxillary dentate. Preorbital process of moderately shallow pars facialis of maxillary well developed. Alary processes of premaxillaries elongate laterally and curved posteriorly. Palatine processes of premaxillaries well developed, not abutting medially. Prevomers reduced slightly anteromedially; not articulating or overlapping sphenethmoid. Dentigerous processes short, horizontally oriented. Bony columella present.

Pectoral girdle arciferal, moderately robust. Omosternum and xiphisternum present. Clavicles slender and abutting medially. Coracoids moderately separated. Scapula bicapitate, slightly shorter than clavicle. Suprascapula about $\frac{2}{3}$ ossified.

Eight prococlous nonimbricate presacral vertebrae. Medial dorsal ossification incom-

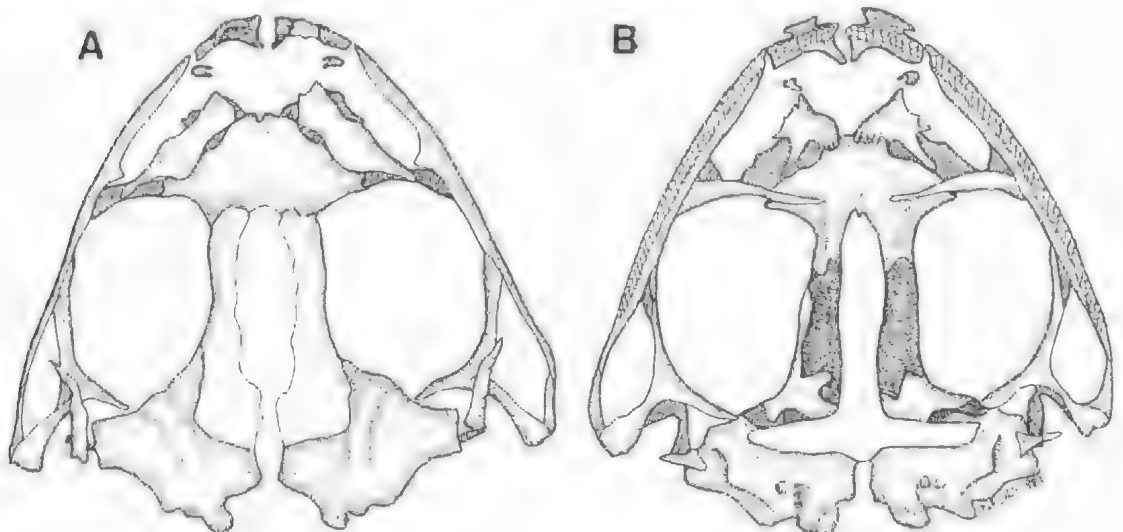


Fig. 10. A. Dorsal and B. ventral view of skull of *Lipotyphlus inermis*. (UAZ A528)

plete on presacrales I, II and III. Relative widths of transverse processes: III > II > IV = sacrum > V > VI > VII > VIII. Sacral diapophyses moderately expanded, ilia extending anteriorly beyond expansion. Bicondylar sacrococcygeal articulation. Well developed crest extending $\frac{1}{2}$ length of urostyle.

Phalangeal formula of hand 3,3,4,4; well developed bony prepollex. Phalangeal formula of foot 3,3,4,5,4; well developed bony prehallux. Terminal phalanges claw shaped.

Variation

Ossification of the sphenethmoid varies between specimens—the foregoing description applies to minimal ossification of the roofing



Fig. 12. Mouthparts of a larva, stage 37, of *Litoria inermis* from Blencoe Falls, Qld. Scale bar = 1 mm.

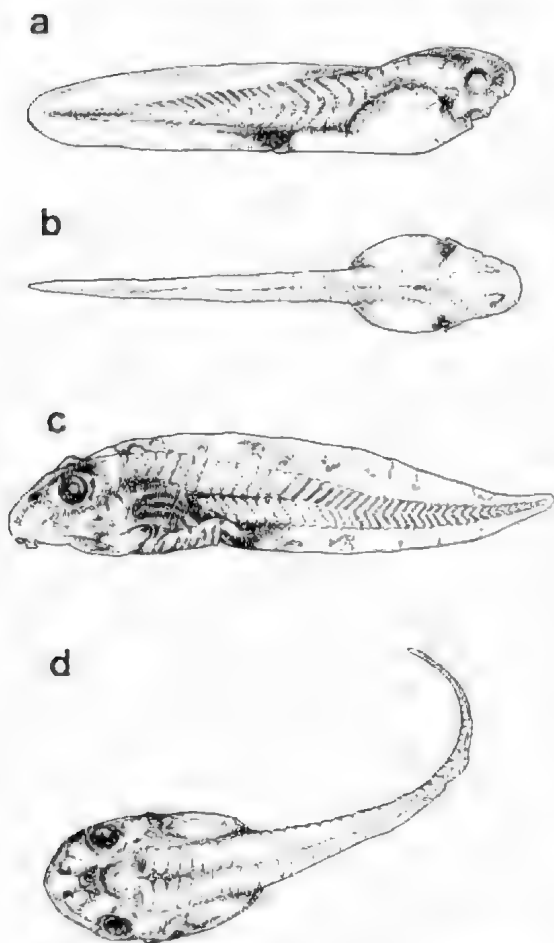


Fig. 11. a, Dorsal and b, lateral views of embryo at stage 20, and c, dorsal and d, lateral views of larva at stage 36 of *Litoria inermis*. Total length of embryo 4.5 mm, body length 1.9 mm, total length of larva 30.5 mm, body length 12.5 mm.

bones. In other specimens, the sphenethmoid is well ossified extending between and to the anterior extremities of the nasals dorsally and anteriorly to the vomerine teeth ventrally. Variation also occurs in the degree of crenulation of the medial edges of the frontoparietals and in the length of the cultriform process of the parasphenoid.

Breeding Biology

Call: *Litoria inermis* usually calls from open gravelly or sandy areas, often on steep sloping banks within 1–2 m of water. At Jabiru, males were heard calling between the middle of November and the middle of March (Tyler *et al.* 1983).

The short call is a staccato note with little tuning; the long call is at least twice the duration of the short call (Table 1, Fig. 6).

Early development: Described by Tyler *et al.* (1983). The morphology of embryos at stage 20 and larvae at stage 36 is shown in Fig. 11. The eyes are more dorsally situated than in larvae of other members of the complex. The mouthparts of a larvae at stage 37 are shown in Fig. 12.

Distribution

Litoria inermis is found across the north of Australia from Mitchell Plateau in W.A. to Cape York in Qld and south to Rockhampton (Fig. 13). Syntypes were collected at Rockhampton and Bowen in Queensland.

The species is an open forest dweller and tends to avoid thick grass, preferring open areas of sparse, low vegetation. In Queensland *L. inermis* is sympatric with *L. latopalmata*



Fig. 13. Distribution of *Litoria inermis* in Australia. Open symbols are literature records and closed symbols are specimens examined during this study. Stars indicate type localities.

and at Jabiru in the Northern Territory with both *L. tornieri* and *L. pallida*.

Comparison with other species

Litoria inermis can be distinguished from all terrestrial congeners, except for members of the *L. aurea*, *L. freycineti* and *L. latopalmata* species groups, by the poorly expanded terminal discs on its fingers and toes. It is distinguished from members of the *L. aurea* species group by gross size and habitus and from the *L. freycineti* group by its relatively shorter hind limbs. From *L. tornieri*, *L. latopalmata* and *L. pallida*, *L. inermis* is distinguished by its tubercular dorsum, finely reticulated thigh markings and poorly developed canthal streak. The pulse repetition rates of both long and short calls of *L. inermis* are higher than those of the other species in this group.

Litoria tornieri (Neiden)

FIGS 2, 4, 6, 7, 14–17

Pelodytes affinis Gray, 1842, Zool. Misc. London 3:56

Hyla affinis: Boulenger 1882 p. 413

Hyla tornieri: Nieden 1923 (nomen substitutum pro *Pelodytes affinis*) p. 228

Hyla latopalmata latopalmata: Copland 1957 (partim) p. 94

Litoria latopalmata: Tyler 1971 (partim) p. 353

Litoria tornieri: Cogger & Linder 1974 p. 71

Litoria affinis: Duellman 1977 p. 114

Definition: A small ground dwelling species (males 28–36 mm, females 27–34 mm) characterised by basal webbing between the fingers, poorly developed terminal discs, first

finger longer than second, moderately short hind limbs ($TL/S-V$ 0.57 ± 0.04 , $0.49-0.68$), well developed lateral headstripe, continuous stripe along outside edge of tibia, smooth brown/grey dorsum, reddish in breeding season.

Description: Based on SAM R18686 a male specimen collected in a pool 800 m W of Gulungul Creek Crossing, Arnhem Highway, N.T. by G. A. Crook on 1.ii.1979.

Head longer than broad (HL/HW 1.30); head length more than $1/3$ snout to vent length ($HL/S-V$ 0.4). Snout prominent, projecting in profile; slightly rounded when viewed from above and in profile. Nostrils more lateral than superior, their distance from end of snout $2/3$ that from eye. Distance between eye and naris less than internarial span ($E-N/IN$ 0.84). Canthus rostralis slightly defined and curved, its nature accentuated by dark rostral stripe. Eye relatively small and inconspicuous, diameter about $1\frac{1}{2}$ times eye to naris distance. Tympanum completely visible, diameter $2/3$ eye diameter (Fig. 15).

Vomerine teeth on short elevations between choanae. Tongue broadly oval.

Fingers long and slender lacking lateral fringes; in order of length $3 > 4 > 1 > 2$ (Fig. 14). Basal webbing between fingers 2 and 3 and 3 and 4. Terminal discs poorly developed, not extending laterally beyond the edges of penultimate phalanx. Subarticular and palmar

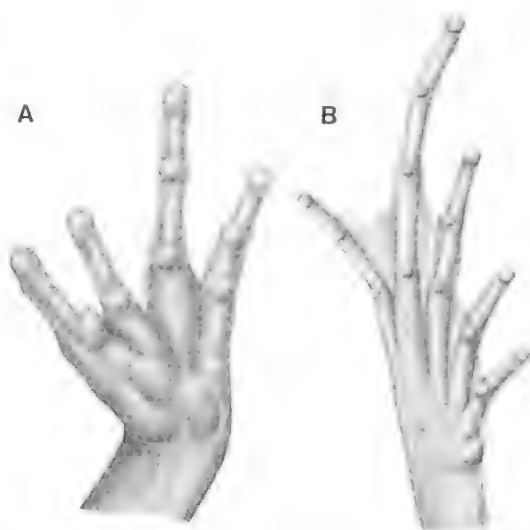


Fig. 14. A. Palmar view of hand and B, plantar view of foot of *Litoria tornieri* (SAM R19572).

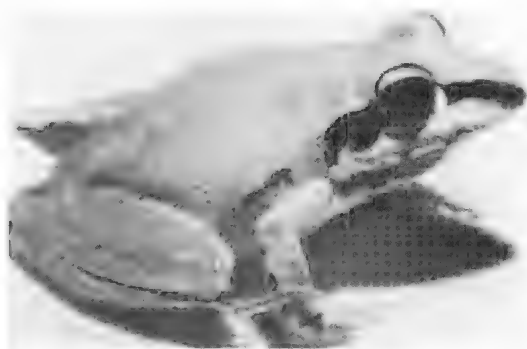


Fig. 15. *Litoria tornieri*, in life (Jabiru, N.T.).

tubercles prominent. Hind limbs moderately long (TL/S-V 0.59). Toes in order of length $4 > 3 > 5 > 2 > 1$ (Fig. 14). Webbing reaching subarticular tubercle on penultimate phalanx of toe 4. Subarticular tubercles prominent. Small oval inner and tiny rounded outer metatarsal tubercles.

Dorsum smooth, abdomen coarsely granular. Submandibular area smooth and pigmented. Moderately well developed tarsal fold on proximal portion of tarsus. Poorly developed supratympanic fold.

Colour in preservative, brownish grey with conspicuous very dark headstripe; anteriorly to nostril, headstripe extending diffusely to tip of snout; between eye and nostril headstripe sharply delineated and interrupted by pale preocular bar (Fig. 2) behind eye, stripe extending above and through tympanum to insertion of forearm; two dark patches prominent in axillary region. Broad white stripe from preocular bar to posterior extremity of mandible.

Backs of thighs heavily pigmented by continuous dark bands separated by continuous stripe and occasional patches of pale ground colour (Fig. 4).

Continuous dark brown stripe along outside edge of tibia and ventral surface of tarsus. Prominent dark brown patch on wrist and edge of forearm.

Well developed glandular nuptial pad on thumb.

Material examined: Holotype, BMNH 1947.2.22.73, Port Essington, N.T., and 50 other specimens. Northern Territory: SAM R18653-73, Jabiru Airstrip; SAM R18687, R16779, Katherine R., 7 km W Katherine Gorge; SAM R9072, 5 km N Mainoru; SAM R14775E.C., 16 km S Hooker; SAM R18679, Cannon Hill; SAM R18682,

Birndu; SAM R18685, E Gulungul Ck; SAM R18683, Arnhem Highway nr Mudginberry Fence; SAM R18684, Coonjimba Billabong; SAM R18680-1, Retention Pond No. 2, Djalkmarra Ck; SAM R19572, Buffalo Billabong, 9 km NW Jabiru; AM R32071-3, R32114-6, Port Essington; SAM R18676-7, 16 km S Woolner; SAM R18678, Berry Ck; UAZ A232, Batchelor, Finnis River; UAZ A523-4, A610-2, Jabiru Airstrip; Western Australia: WAM R57194, Pago Mission Ruins, Mission Cove, Napier-Broome Bay; WAM R50670-1, Drysdale R. N.P., 14°44'S, 126°56'E.

Variation

Small frog (males 27-34 mm, females 28-36 mm). Head longer than broad (HL/HW 1.23 ± 0.12 , 1.09-1.35). Head length $1/3 - \frac{1}{2}$ snout to vent length (HL/S-V 0.37 ± 0.02 , 0.31-0.42). Hind limbs short (TL/S-V 0.57 ± 0.04 , 0.49-0.68). Anterior head region relatively broad with variable E-N/IN (0.75 ± 0.10 , 0.61-1.03).

As indicated by these measurements, *L. tornieri* exhibits limited variation in body form and has the shortest hind limbs of all members of the *L. latopalmata* species group.

In colouration, *L. tornieri* is the least variable member of the species group. Mottling of the dorsal and dorsolateral surfaces has not been observed, but in preservative the colour tends to fade and varies from brownish to grey. This variation is probably a reflection of the breeding condition of the specimens as sexually mature calling males tend to be a distinct reddish-brown colour.

The uninterrupted, narrow, dark stripe on the anterior edge of the tibia is consistently present and is an excellent character distinguishing this species from sympatric members of the *L. latopalmata* species group. However, the dark pigment spots in the axilla are sometimes absent.

Osteology

Skull relatively fragile with moderately ossified neurocranium. Sphenethmoid moderately ossified extending between but not anteriorly to nasals dorsally and just anteriorly to dentigerous processes of premaxillae ventrally. Nasals lying alongside not overlapping sphenethmoid (Fig. 16A). Prootic and exoccipital fused. Exoccipital not ossified dorso- or ventromedially. Crista parotica well developed, short and stocky. Otic ramus of squamosal not articulating with distal extremities. Frontoparietal fontanelle extensive,

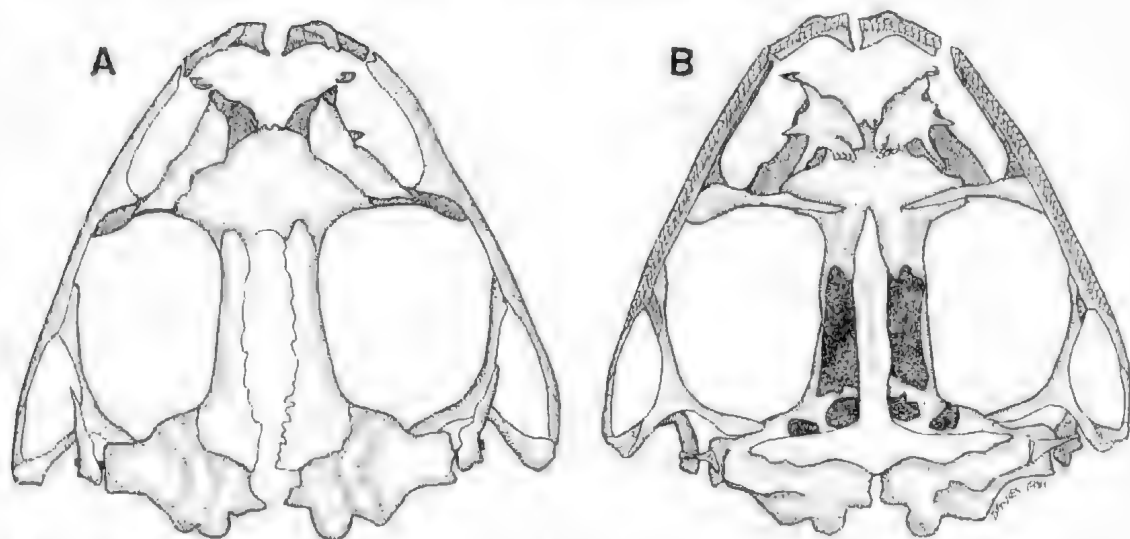


Fig. 16. A, Dorsal, and B, ventral views of skull of *Litoria tornieri* (UAZ A681).

reaching anteriorly to level of palatines; posteriorly undelineated because of lack of medial ossification of exoccipital. Orbital edges of frontoparietals straight.

Maxillary process of nasals moderately sharp, not articulating with well developed preorbital process of pars facialis of maxillary. Palatines expanded distally, slender medially overlying sphenethmoid. Parasphenoid slender; cultriform process long, slender reaching between palatines; alae long, at right angles to cultriform process and overlapped by medial arm of pterygoid.

Pterygoid moderately robust, in moderately long contact with moderately developed pterygoid process of palatal shelf of maxillary. Medial arm long, not in bony contact with prootic region.

Quadratojugal slender, fully articulated. Squamosal slender, otic ramus expanded and slightly longer than acuminate zygomatic ramus. Maxillary and premaxillary dentate. Preorbital process of moderately shallow pars facialis of maxillary well developed. Alary processes of premaxillaries elongate laterally, curved posterolaterally. Palatal processes of premaxillaries well developed, not abutting medially. Prevomers slightly reduced medially. Dentigerous processes short, angled slightly to midline. Bony columella present.

Pectoral girdle arciferal and moderately robust. Omosternum and xiphisternum present. Clavicles slender, equal in length to scapula

and abutting medially. Coracoids moderately separated. Suprascapular about 2/3 ossified.

Eight prococlous nonimbricate presacral vertebrae. Medial dorsal ossification incomplete on presacrals I, II, III and IV. Relative widths of transverse processes III > IV > II > sacrum > V > VI > VII > VIII > VII. Sacral diapophyses moderately expanded, ilia extending anteriorly beyond expansion. Bicondylar sacrococcygeal articulation. Well developed crest extending \pm length of urostyle.

Phalangeal formula of hand 3,3,4,4; well developed bony prepollex. Phalangeal formula of foot 3,3,4,5,4; well developed bony prehallux. Terminal phalanges knobbed.

Variation

Well expanded otic ramus of squamosal lies alongside crista parotica in some specimens. Pterygoid process of palatal shelf of maxillary absent to variously developed.

Breeding Biology

Call: Males call from cover either under leaves or at the base of grass tussocks within 3 m of water. At Jabiru, N.T., males were heard calling in early November and early March (Tyler *et al.* 1983). Calls are well tuned, with most of the energy below 2000 Hz (Table 1, Fig. 6).

Early development: Tyler *et al.* (1983) describe eggs and larvae of this species. Embryos at stage 20 and larvae at stage 33 are illustrated in Fig. 17.

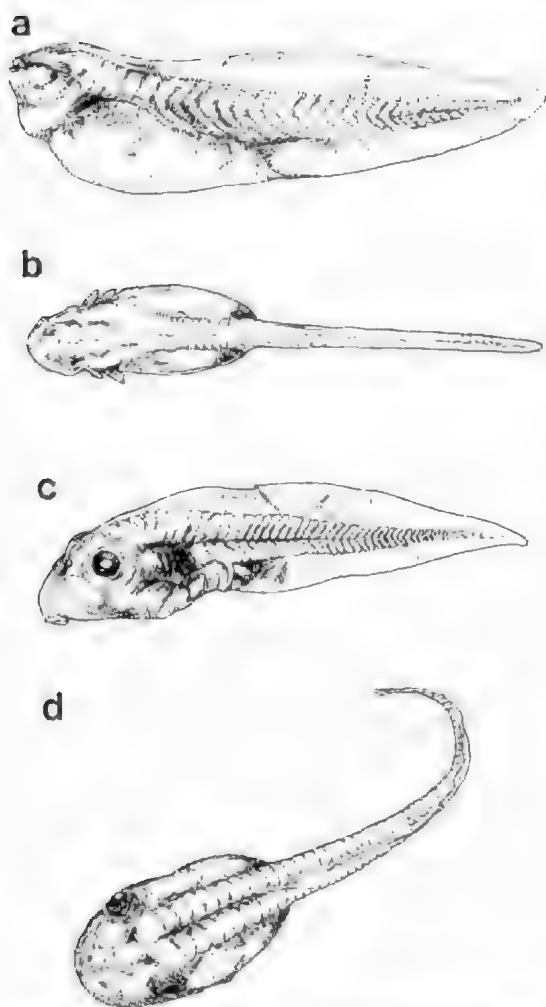


Fig. 17. a, Dorsal and b, lateral views of embryo at stage 20, c, dorsal and d, lateral views of larva at stage 33, of *Litoria torrieri*. Total length of embryo 4.5 mm, body length 2.3 mm, total length of larva 28.5 mm, body length 11.0 mm.

Distribution

Litoria torrieri has the most restricted distribution of the ground hylid species (Fig. 7). The type locality is Port Essington on the Coburg Peninsula in the Northern Territory and the species is confined to the north of the Northern Territory and Western Australia. The southernmost record is 16 km S of Hooker, N.T. The species is an open forest dweller and is sympatric with *L. inermis* and *L. pallida* at Jabiru, N.T.

Comparison with other species

Litoria torrieri can be distinguished from all terrestrial congeners, other than the *L. aurea*,

L. freycineti and *L. latopalmata* species groups, by the unexpanded terminal discs on the fingers and toes. From members of the *L. aurea* group it can be distinguished by their gross size and habitus and from the *L. freycineti* group by relatively shorter hind limbs. From *L. pallida*, *L. inermis* and most specimens of *L. latopalmata*, *L. torrieri* can be distinguished by the presence of an uninterrupted brown stripe on the outer side of the tibia. From those specimens of *L. latopalmata* possessing such a stripe, *L. torrieri* can be distinguished by its less expanded discs (not extending laterally beyond the fringes of the penultimate phalanx), its smaller size (males 27–34 mm, females 28–36 mm, compared with males 29–39 mm, females 36–42 mm) and its relatively shorter hind limbs (TL/S–V 0.57 ± 0.04 in *L. torrieri*, 0.64 ± 0.03 in *L. latopalmata*). *L. torrieri* has longer short calls than any other member of the group.

Litoria pallida sp. nov.

FIGS 2, 4, 6, 18–22

Litoria latopalmata: Tyler 1968 (*partim*) p. 719

Holotype: SAM R19555, a male collected at Gulungul Creek Crossing, Arnhem Highway, N.T., 12°39' S, 132°52' E, by G. A. Crook on 10.xii.1978.

Definition: A small highly variable ground dwelling species (female 31–37 mm, male 27–34 mm) characterised by unwebbed fingers, poorly expanded fingers discs, first finger considerably longer than second; long hind limbs (TL/S–V 0.62 ± 0.04); well developed stripe on side of head; smooth or mottled dorsum, sometimes faintly tubercular.

Description of holotype: Head longer than broad (HL/HW 1.18); head length more than one third snout to vent length (HL/S–V 0.38). Snout prominent, projecting in profile (Fig. 2) and slightly rounded when viewed from above and in profile. Nostrils more lateral than superior, distance from end of snout $\frac{1}{2}$ that from eye. Distance between eye and naris equal to internarial span (E–N/IN 1.00). Canthus rostralis moderately well defined and straight, its nature accentuated by dark rostral stripe. Eye relatively small and inconspicuous, diameter slightly greater than eye to naris distance. Tympanum completely visible, diameter about \pm eye diameter (Fig. 18).



Fig. 18. *Litoria pallida*, in life (Jabiru, N.T.).

Vomerine teeth on short oval elevations between anterior edges of choanae. Tongue broadly oval.

Fingers moderately long and slender lacking lateral fringes (Fig. 19A); in order of length $3 > 1 > 4 > 2$. Fingers unwebbed. Terminal discs poorly developed, not extending beyond lateral extremities of penultimate phalanx. Subarticular and palmar tubercles prominent. Many supernumerary tubercles present.

Hind limbs long (TL/S-V 0.62). Toes in order of length $4 > 3 > 5 > 2 > 1$ (Fig. 19B). Webbing reaches midpoint of penultimate phalanx on toe 5 and to level of subarticular tubercle at base of antepenultimate phalanx of toe 4. Subarticular tubercles prominent. Small oval inner and smaller rounded outer metatarsal tubercles.

Dorsum smooth; abdomen, pectoral region and undersurface of thighs coarsely granular; submandibular area smooth. Well developed proximal tarsal fold; moderately developed supratympanic fold.

Colour in preservative: dorsum grey and hind limbs brown with conspicuous very dark stripe extending from nostril to eye, interrupted

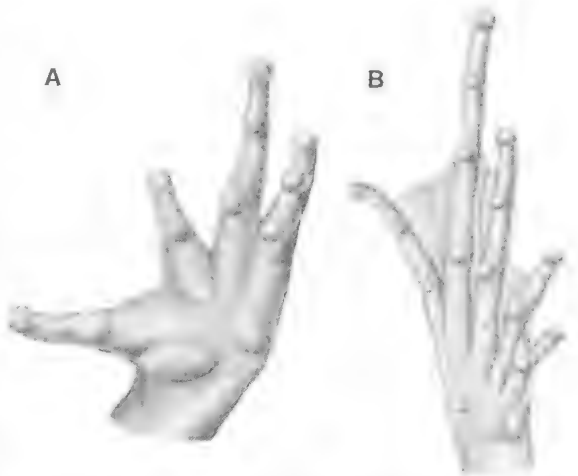


Fig. 19. A, Palmar and B, plantar view of hand and foot of *Litoria pallida* (SAM R19539).

by a white preocular bar. Posteriorly stripe extends through and above tympanum, terminating above insertion of forearm. Disrupted dark spots extend halfway along flank. White stripe extends from lower margin of eye to insertion of forearm.

High markings dark, separated from ground colour by pale yellow patch contiguous with irregular dorsal margin; dark markings commonly disrupted and extensively marked by lighter markings (cf. Fig. 4). Disrupted brown patches extend along edge of tibia; plantar surface of tarsus and foot uniformly brown.

Brown, glandular, bilobed nuptial pad; throat moderately suffused with pigment.

Dimensions of holotype: S-V 31.7 mm; TL 19.7 mm; HL 12.0 mm; HW 10.2 mm; E-N 3.1 mm; IN 3.1 mm; E 3.7 mm; T 2.9 mm

Etymology: The specific name is derived from the Latin *pallidus* meaning pale, ashen, in reference to the predominant colour of the dorsum.

Variation

There are 171 paratypes:

Northern Territory: SAM R19539, 4 km W Baradil Ck, 30.xi.1978, G. A. Crook, M. Davies, M. J. Tyler (illustrated); SAM R19549, 40 km N Elliott, 16.xii.1980, M. Davies, A. A. Martin, M. J. Tyler; SAM R19451-4, Jabiru Airstrip, 7.xii.1979, G. A. Crook; SAM R19455-7, Jabiru Airstrip, 4.xi.1978, G. A. Crook; SAM R19458, R19491-504, 30 m N Retention Pond No. 2, Djalkmarra Ck, Ranger Uranium Lease, 5.xii.1979, G. A. Crook; SAM R19459-62, small pools, 100 m upstream Coonjimba Billabong, 5.xii.1979, G. A. Crook; SAM R19463, R19474-90, Cannon Hill, 1.viii.1976, M. King; SAM R19464, soak from one body, Jabiru, 29.xi.1978, M. Davies, M. J. Tyler; SAM R19465, 4 km W Baradil Ck, 30.xi.1978, M. Davies, M. J. Tyler; SAM R19466-9, McArthur River bridge on road to McArthur R. Sta, 24.iv.1979, G. A. Crook; SAM R19470-1, Gulgungul Swamp, 150 m SE Gulgungul Ck Crossing, Arnhem Highway, 1.ii.1979, G. A. Crook; SAM R19472-3, 800 m W Gulgungul Ck Crossing, Arnhem Highway, 1.ii.1979, G. A. Crook; SAM R19506, Coonjimba Billabong, 23.x.1978, G. A. Crook; SAM R19507, Jabiru Airstrip, 29.xi.1978, M. Davies, M. J. Tyler; SAM R19511-3, Collyer Lagoon, Carpentaria Highway, 26.ix.1977, G. A. Crook, W. Zeidler; SAM R19514-33, Lake Woods, nr Elliot, 5.x.1977, G. A. Crook, W. Zeidler; SAM R19540-48, Bullman Hstd, 8.viii.1966, R. Edwards; SAM R9062-3, 133 km N Mainoru, 23.viii.1967, R. Edwards, Fleming; SAM R14775, R19508-9, 16 km S Hooker, 5.vi.1975, A. Robinson; AMNH 108333-4, Coonjimba Billabong, 23.x.1978, G. A. Crook; WAM R73573, Ja Ja borrowpit at entrance to Pan-Continental Campsite, 28.xi.1977, M. Davies, M. J. Tyler; KU188433-4, Cannon Hill, 28.xi.1977, M. Davies, M. J. Tyler; AM R97183-5, Ja Ja borrowpit nr Pan Continental Camp, 28.xi.1977, M. Davies, M. J. Tyler; NTM R10098-9, Cannon Hill, 28.xi.1977,

M. Davies, M. J. Tyler; QM J39256-8, Ja Ja borrowpit at entrance to Pan Continental Campsite, 28.xi.1977, M. Davies, M. J. Tyler; SAM R19550-1, Jabiru Airstrip, 10.i.1981, M. Cappel, M. Davies, M. J. Tyler (cleared and stained); SAM R19552, 100 m E Jim Jim turnoff, Arnhem Highway, 9.i.1981, M. Cappel, M. Davies, M. J. Tyler, G. F. Watson (cleared and stained); SAM R19553-4, roadside pool, 800 m W, Gulgungul Crossing, Arnhem Highway, 1.ii.1979, G. A. Crook (cleared and stained).

Queensland: SAM R14774, R19510, 19 km N Laura, 23.x.1974, A. R. Robinson; QM J41013-6, J41018, Coen Airport, 6.iii.1979, R. G. Atherton, K. R. McDonald; QM J41019, Lakefield N. P., nr Lakefield Hstd, 25.ii.1981, B. J. Lyon, K. R. McDonald (recorded); QM J41017, Coen Airport, 6.iii.1979, R. G. Atherton, K. R. McDonald (recorded).

Western Australia: SAM R19535, Camballin, 18.ii.1980, M. Davies, A. A. Martin, M. J. Tyler; SAM R19536-8, 175 km E Broome, 17.ii.1980, M. Davies, A. A. Martin, M. J. Tyler; WAM R73574, 30-35 km S Dunean Highway/N Highway Jcn, 5.ii.1978, A. A. Martin, M. J. Tyler; WAM R73577, Hidden Valley, Kununurra, 1.ii.1978, M. Davies, A. A. Martin, M. J. Tyler; WAM R73575, Camballin, 18.ii.1980, M. Davies, A. A. Martin, M. J. Tyler; WAM R73576, 175 km E Broome, 17.ii.1980, M. Davies, A. A. Martin, M. J. Tyler.

Adult males measure 27-34 mm and females 31-37 mm. Hind limb length is variable, but usually moderately long 0.62 ± 0.04 , $0.53-0.72$; head length is always longer than head width (1.29 ± 0.06 , $1.17-1.42$) and the head length is always greater than one third of the snout to vent length ($HL/S-V$ 0.39 ± 0.02 , $0.36-0.42$). Eye to naris distance to inter-narial span ratio highly variable ($E-N/IN$ 0.89 ± 0.10 , $0.68-1.12$) but usually less than 1.

Variation occurs in dorsal colouration and texture. In some specimens dorsum grey/brown with brown mottlings (Fig. 18), in others, dorsum and dorsal surface of thighs grey. Disrupted dark markings along edge of tibia not always present, nor are markings on anterior surfaces of thighs. Mottling on back can be conspicuous or patchy. In some specimens dorsum weakly tubercular with tubercles aligned longitudinally along back. White stripe below eye appears cream in some specimens and well-developed variegations can be found around lips.

Osteology

Skull moderately well ossified; sphenethmoid well ossified extending to anterior ex-

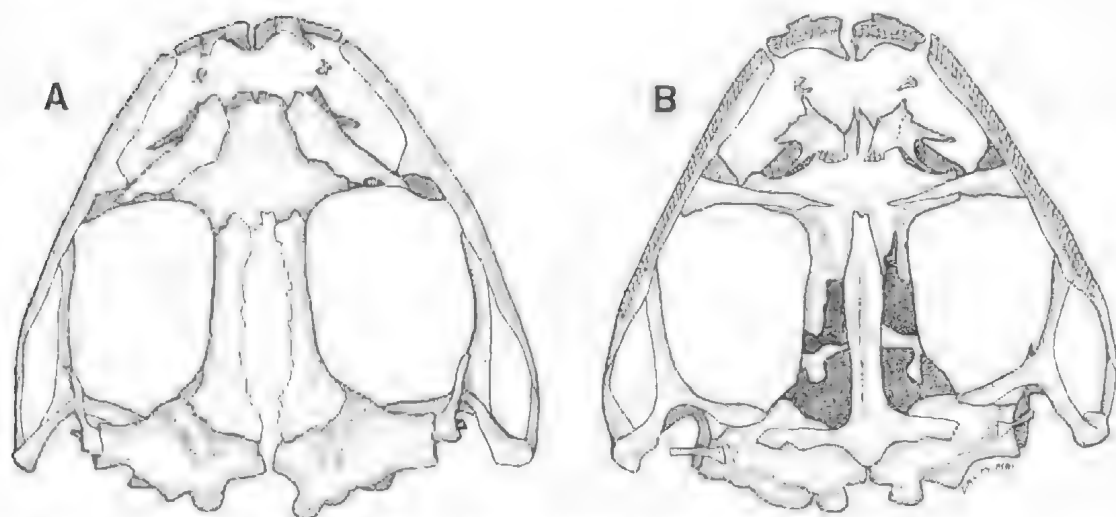


Fig. 20. A, Dorsal and B, ventral view of skull of *Litoria pullida* (SAM R19553).

processes of premaxillaries well developed, not abutting medially. Alary processes of premaxillaries elongate laterally, curved posterolaterally. Prevomers reduced slightly medially. Dentigerous processes short, horizontally oriented. Bony columella present.

trémities of nasals dorsally and just anteriorly to dentigerous processes of prevomers ventrally. Nasals overlying sphenethmoid along their medial edges. Prootic and exoccipital fused but medial fusion absent in exoccipital. Crista parotica moderately well developed, short and stocky, barely overlapped laterally by moderately expanded otic ramus of the squamosal. Frontoparietal fontanelle extensive, reaching anterior extremity of orbit (Fig. 20A). Posterior margin undelineated due to lack of medial fusion of exoccipital. Orbital edges of frontoparietals straight.

Nasals moderately large, widely separated medially. Maxillary processes acuminate and articulate with well developed preorbital process of pars facialis of maxillary. Palatines expanded distally, very slender and acuminate medially overlying sphenethmoid.

Parasphenoid robust. Cultriform process moderately broad, irregularly truncate and reaching almost to level of palatines (Fig. 20B). Alae moderately long, at right angles to cultriform process and barely overlapped by medial arm of pterygoid. Pterygoid moderately robust. Anterior arm in moderately long contact with poorly developed pterygoid process of palatal shelf of maxillary. Medial arm slightly expanded distally.

Quadratojugal slender and fully articulated. Squamosal moderately robust. Zygomatic ramus slender and slightly shorter than moderately expanded otic ramus of squamosal. Maxillary and premaxillary dentate. Palatine

processes of premaxillaries well developed, not abutting medially. Alary processes of premaxillaries elongate laterally, curved posterolaterally. Prevomers reduced slightly medially. Dentigerous processes short, horizontally oriented. Bony columella present.

Pectoral girdle arciferal and moderately robust. Omosternum and xiphisternum present. Clavicles slender and abutting medially. Coracoids moderately separated. Scapula slightly shorter than clavicles. Suprascapula about 2/3 ossified.

Eight procoelous, nonimbricate, presacral vertebrae. Medial, dorsal ossification incomplete on vertebrae I, II, III and IV. Relative widths of transverse processes: III > IV > II > sacrum > V > VI > VII > VIII. Sacral diapophyses moderately expanded, ilia extend anteriorly beyond the expansion. Sacrococcygeal articulation bicondylar. Well-developed crest extending for about 1/3 length of urostyle.

Phalangeal formula of hand 3,3,4,4. Well-developed bony prepollex. Phalangeal formula of foot 3,3,4,5,4. Well-developed bony prehallux. Terminal phalanges claw shaped.

Variation

Well-developed preorbital process of pars facialis of maxillary not always articulating with maxillary process of nasal. Distal expansion of medial arm of pterygoid not occurring to same extent in all specimens. Degree of ossification of sphenethmoid varies and hence its relationship with nasal and prevomers.

Breeding Biology

Call: Males call in open areas within 1 m of water. At Jabiru, N.T., males were first heard calling in early November, and last heard in early March (Tyler *et al.* 1983).

This species shows the greatest differentiation between long and short calls, with the former having at least 10 times the duration of the latter (Table 1, Fig. 6). There are complex frequency shifts and multiple harmonic bands in both calls, and a considerably more exhaustive analysis is required to fully elucidate the call structure.

Early development: Tyler *et al.* (1983) have described development in this species (as

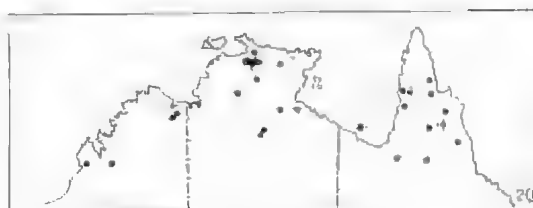


Fig. 22. Distribution of *Litoria pallida* in Australia. Star indicates type locality.

"*Litoria* sp. nr *latopalmata*"). An embryo at stage 20 and a larva at stage 34 are illustrated in Fig. 21.

Distribution

Litoria pallida is confined to the north of Australia from Broome in W.A. to Cape York in Qld, above latitude 20° (Fig. 22). Like the other ground hyliid species it is an open forest dweller and is sympatric with *L. inermis* on Cape York and *L. tornieri* and *L. inermis* at Jabiru, N.T.

Comparison with other species

Litoria pallida can be distinguished from all terrestrial congeners except the *L. aurea*, *L. freycineti* and *L. latopalmata* species groups by the unexpanded discs on the fingers and toes. It can be distinguished from members of the *L. aurea* group by its size and habitus and from the *L. freycineti* group by its relatively shorter hind limbs.

From *L. tornieri*, *L. pallida* can be distinguished by the absence of a continuous stripe along the outside edge of the tibia, and by its relatively longer legs (TL/S-V 0.62 ± 0.04 in *L. pallida*, 0.57 ± 0.04 in *L. tornieri*). It can be distinguished from *L. latopalmata*, the species with which it has been confused, by its smaller size (males 27–34 mm, females 31–37 mm compared with 38–37 mm males and 36–42 mm females in *L. latopalmata*) and poorly expanded discs which do not project beyond the lateral edges of the penultimate phalanges of fingers and toes. *Litoria pallida* can be distinguished from *L. inermis* by its well-developed lateral headstripe, strongly marked thighs and relatively smooth dorsum. As mentioned above, the call structure of *L. pallida* is particularly distinctive.

Other material examined: QM J27228, 12 mile Creek on Normanton–Kariumba Rd. Qld; QM J28916, Norman Creek Rd to Norman; QM J31369, along Glen Esk Rd near Esk, Qld; SAM R9710, Strathgordon Hstd Qld; SAM R9720, Edward River Hstd Qld; SAM R9660, Edward

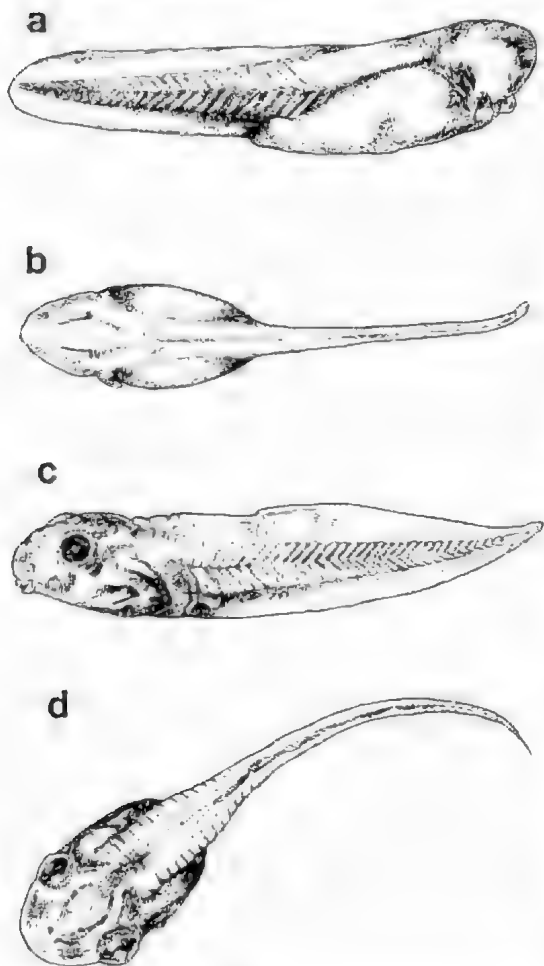


Fig. 21. a, Lateral and b, dorsal view of embryo at stage 20, and c, lateral and d, dorsal view of larva at stage 34, of *Litoria pallida*. Total length of embryo 4.4 mm, body length 2.3 mm, total length of larva 30 mm, body length 10.5 mm.

River, Qld; SAM R4935 Mornington Island; SAM R8174, R19534, Mulliman Hstd, N.T.; WAM R62889-62898, upper reaches McKinley River, N.T.; SAM R19632-47, McArthur River Bridge on road to McArthur River Stn; SAM R19622-31, Lake Woods, nr Elliott, N.T.; SAM R19614-21, Collyer Lagoon (just off Carpentaria Highway), N.T.; SAM R19655-68, Coomalie Creek, 25 km N Adelaide River, N.T.; SAM R9417, Mitchell River Mission, Qld; SAM R9680, R9699, Hann River, N. Qld; SAM R9885, R9876, R9841, Strathgordon Hstd, Qld; SAM R9714, Edward River Stn, Qld; SAM R9719, Laura River, Qld; SAM R9868, R9852, Hann River/Kennedy Rd, Qld.

Discussion

Many cryptic species have been described amongst those frogs exhibiting wide geographic ranges across the north of Australia and down the eastern seaboard. Since Moore's (1961) definitive work on the frogs of New South Wales, *Litoria bicolor* (Gray), *Cyclorana australis* (Gray) and *C. brevipes* (Peters) have been shown to consist of such cryptic species pairs resulting in the resurrection or description of *L. fallax* (Peters), *C. novaehollandiae* Steindachner and *C. longipes* Tyler & Martin.

Ground hylids of the *Litoria latopalmata* species group have for a long time been a taxonomic enigma, particularly because most museum material is poorly preserved and consists of subadult specimens. This latter situation is the result of collections being made in the dry season, when many northern areas are accessible. For this reason, we have not included some of the material examined by us in the type series but have indicated its existence in the text.

The members of the *L. latopalmata* species group are extremely homogeneous in their morphology, osteology, calls and developmental history. Intraspecific variation is common in characters that are usually morphologically reliable such as rugosity of the dorsum, delineation of canthal stripes, tibial markings, back pattern, toe webbing (Moore 1961, Fry 1913, Copland 1955, Tyler 1968b) and development of supernumerary sub-articular tubercles. Osteologically the four species are very conservative. Interspecific differences are slight and often ontogenetically controlled, therefore being of little value.

The call structure is unusually complex among Australian frogs. Neither a typical call sequence nor a typical call duration can be

defined, since calls are produced in very long series of heterogeneous notes. Our categorization of call notes as long and short represents only a first step in describing the acoustic repertoire. It is probable that different behavioural roles are served by the different call elements; it may be, for instance, that short calls have a territorial and long calls a courtship function. However the severe limitations of our data preclude further speculation.

From what is known of other hylid signalling systems, it is probable that pulse repetition rate is a key component indicating species identity (Littlejohn, 1971). The sympatric eastern taxa, *L. latopalmata* and *L. inermis* show clear differences in pulse repetition rate of both long and short calls, though the temperature variation in our samples makes definitive comparisons impossible. *L. inermis* also shows consistent differences in pulse repetition rate from *L. tornieri* and *L. pallida*, but the pulse repetition rate of the latter two is more similar. However they are markedly different in both number of pulses per note and note duration.

Larvae are very similar and typical of Australian *Litoria* (Martin & Watson 1971). *Litoria inermis* larvae can be distinguished from those of *L. pallida* and *L. tornieri* by the dorsal rather than lateral position of the eyes. *Litoria pallida* and *L. tornieri* larvae are indistinguishable until metamorphosis.

Failure to recognize the taxonomic complexity of this group has led to many anomalies in the literature. Andersson (1913) for instance, reported *Chiroleptes inermis* and *Hyla affinis* from the Kimberley Division of Western Australia. The former specimen is readily referable to *L. inermis* as the description and illustration provided are clearly recognisable. The latter specimen cannot be identified from the written description and may represent either *L. tornieri* or *L. pallida*, both of which occur in the area.

Tyler's (1968b) study of frogs of the *L. lesueuri* complex in northwestern Australia included representatives of all three northern species, as *L. latopalmata*. However, Tyler delineated specimens from southern and central Queensland and northern N.S.W. from all other specimens by the degree of dilation of discs, the more extensive webbing and development of supernumerary tubercles on the palmar and plantar surface of the hands and feet exhibited by these specimens. These

are the only non-fugitive characters that we have found reliable in our own analysis. Straughan (1969) referred to Andersson's specimens in his redefinition of *L. inermis* (as *Hyla inermis*) and commented on the relatively shorter tibia length compared with Queensland specimens. He considered this difference to be trivial in view of the wide geographic range of the species. Our studies have shown this difference to be exceedingly constant within the northwestern Australian specimens.

Of the 120 specimens measured from the Northern Territory and northern Western Australia only 13 had a $TL/S-V \geq 0.59$. The mean was 0.57 ± 0.03 with a range of 0.51–0.67. The Queensland specimens showed consistently longer hind limbs ($TL/S-V$ 0.63 ± 0.04 {0.56–0.68 range}) (see Fig. 8). Adams *et al.*¹ could not separate the populations electrophoretically and we cannot separate the calls of the two populations. Hence all specimens are referred to *L. inermis*.

Cogger & Lindner (1974) remarked that the types of *Litoria latopalmata* and *L. inermis* were indistinguishable. These specimens are in poor condition and distinguishing characteristics have become blurred, although the syntype of *L. inermis* housed at the American Museum of Natural History and collected at Bowen is clearly identifiable as that species.

Since both species are sympatric at their type localities and since modern usage of the names *L. latopalmata* and *L. inermis* in reference to species found in N.S.W., southern Queensland and South Australia causes no confusion (Moore 1961, Cogger 1979, Barker & Grigg 1978, Tyler 1977, 1978), it would invite nomenclatorial chaos to question the validity of the current application of the names *L. latopalmata* and *L. inermis*.

The *L. latopalmata* species group definition of Tyler & Davies (1978) should be modified in the following ways:

Dorsum brown, grey or reddish, usually bearing extensive irregular markings of little if any recognisable pattern.

Nasals well developed and separated widely medially. Frontoparietal fontanelle extensive; crista parietica well developed, short and stocky; otic ramus of squamosal slightly expanded, usually lying alongside crista parietica;

palatines expanded laterally, slender distally; prevomers reduced slightly medially; dentigerous processes short; preorbital processes of moderately shallow pars facialis of maxillary well developed; palatine processes of premaxillaries well developed, not abutting medially; alary processes of premaxillaries extended laterally and inclined posterolaterally; quadratojugal fully articulated; otic ramus of squamosal generally slightly longer than zygomatic ramus; parasphenoid large, alae long and at right angles to cultriform process; maxillary and premaxillary dentate; bony columella present.

Pectoral girdle arciferous and moderately robust; slender clavicles abutting medially; phalangeal formula of hand 3.3.4.4; well developed bony prepollex; phalangeal formula of foot 3.3.4.5.4; well developed bony prehallux; eight procoelous nonimbricate presacral vertebrae; dorsal ossification on anterior three vertebrae always incomplete; transverse processes of presacral vertebrae long; sacral diapophyses moderately expanded; ilia extending anteriorly to expansion; well developed urostyle crest extending 2/3 to 1 length of urostyle; sacrocoecygeal articulation bicondylar.

Composition: Four species are included in the group: *Litoria latopalmata* Günther, *L. inermis* (Peters), *L. tornieri* (Nieden) and *L. pallida* sp. nov.

Key to species in *Litoria latopalmata* species group

1. Dorsum tubercular, lateral headstripe poorly defined, thigh markings finely reticulated *L. inermis*
Dorsum usually smooth, lateral headstripe well defined, particularly before the eye, thigh markings strongly reticulated 2
2. Finger discs not extending laterally beyond edge of penultimate phalanx 3
Finger discs extending beyond edge of penultimate phalanx *L. latopalmata*
3. Stripe along edge of tarsus interrupted *L. pallida*
Stripe along edge of tarsus uninterrupted *L. tornieri*

Acknowledgments

We wish to acknowledge the following museums and their respective curators for the loan of material: American Museum of Natural History for a syntype of *L. inermis*, Australian Museum for topotypic *L. tornieri*,

¹ Adams, M., Baverstock, P. R., Tyler, M. J. & King, M. Genetic differentiation among Australian frogs of the family Hylidae. Unpubl. ms.

British Museum (Natural History) for type of *L. latopalmata* and *L. tornieri*, Queensland Museum for Queensland ground hylid representatives, Rijksmuseum van Natuurlijke Historie, Leiden for a syntype of *L. inermis*, and the South Australian Museum for access to its extensive collection of ground hylid material. We are grateful to Graeme Crook, Max King, Greg Miles, Michael Mahony and Keith McDonald for the provision of fresh material and to Graeme Crook and Keith McDonald for calls and field notes of some Northern Territory and Queensland species respectively. Chris Miller is thanked for hours of painstaking tadpole rearing. Linda Truch is responsible for the superb illustrations in Figures 2,3,9,14 and 19. Tadpole illustrations

are the work of Peter Preuss. Audiospectrographic analyses were carried out by Peter Harrison. We are grateful to Michael Tyler for hours of consultation and encouragement. Field work was supported by an Australian Research Grant Committee award to M. J. Tyler, Amax Exploration, Utah Foundation, Ian Potter Foundation and the Office of the Supervising Scientist East Alligator River Region. We are grateful to Michael Tyler, John Bishop, Bill Duellman and Simon Fisher for assistance in the field. Ansett Airlines of Australia transported live material safely to Adelaide and we particularly thank Mr G. Mewett and Mr B. Pennington. Jean Russell-Price typed drafts of the manuscript and the final copy.

References

- ANDERSSON, I. G. (1913) Results of Dr. E. Mjöberg's Swedish scientific expeditions to Australia 1910-1913. IV. Batrachians. *Kungl. Svenska Vetenskap. Handl.* 52(4), 3-26.
- BARKER, J. & GRIGG, G. (1977) "A field guide to Australian frogs." (Rigby: Adelaide.)
- BOULENGER, G. A. (1882) Catalogue of the Batrachia Salientia s. Ecaudata in the Collection of the British Museum. 2nd Edition. London, 1-503.
- COOPER, H. G. (1979) "Reptiles and amphibians of Australia." 2nd Edition. (Reed: Sydney.)
- & LINDNER, D. A. (1974) Frogs and Reptiles. in H. J. Eirth & J. H. Calaby (Eds) "Fauna Survey of the Port Essington District, Coburg Peninsula, Northern Territory of Australia. CSIRO, Division of Wildlife Research Tech. Pap. (28.)
- COPLAND, S. J. (1957) Presidential address. Australian tree frogs of the genus *Hyla*. *Proc. Linn. Soc. N.S.W.* 82, 9-108.
- DAVIS, D. D. & GORE, V. R. (1947) Cleaning and staining specimens of small invertebrates. *Fieldiana: Techniques* 4, 1-16.
- DUELLMAN, W. F. (1977) Liste der rezenten Amphibien und Reptilien Hylidae, Centrolenidae, Pseudidae. *Das Tierreich* 95, 1-225.
- FRY, D. B. (1913) On a *Varanus* and a frog from Burnett River, Queensland and a revision of the variations in *Limnodynastes dorsalis* Gray. *Rec. Aust. Mus.* 10, 17-34.
- GOSNER, K. L. (1960) A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* 16, 183-190.
- LITTLWOOD, M. J. (1971) A reappraisal of mating call differentiation in *Hyla cadaverina* (= *Hyla californica*) and *Hyla regilla*. *Evolution*, 25, 98-102.
- MARTIN, A. A. & WATSON, G. F. (1971) Life history as an aid to generic delimitation in the family Hylidae. *Copeia* (1971), 78-79.
- MOORE, J. A. (1961) Frogs of eastern New South Wales. *Bull. Am. Mus. Nat. Hist.* 121(3), 149-386.
- NIEDEN, FR. (1923) Anura I in C. Apstein, (ed.) *Das Tierreich*, 46, 1-584.
- PARKER, H. W. (1940) The Australasian frogs of the family Leptodactylidae. *Novitates Zool.* 42, 1-106.
- SLEVIN, J. R. (1955) Notes on Australian amphibians. *Proc. Californian Acad. Sci.* 28, 355-392.
- STRAUGHAN, I. R. (1969) *Hyla inermis* (Peters) a species hitherto erroneously referred to the leptodactylid genus *Cyclorana* (Anura, Hylidae/Leptodactylidae). *Zool. Meded.* 43(17), 207-212.
- TRUEB, L. (1979) Leptodactylid frogs of the genus *Telmatobius* in Ecuador, with the description of a new species. *Copeia* 1979 (4), 714-733.
- TYLER, M. J. (1962) On the preservation of Anuran tadpoles. *Aust. J. Sci.* 25, 222.
- , (1968a) Papuan hylid frogs of the genus *Hyla*. *Zool. Verh. Rijksmus. Nat. Hist. Leiden* 96, 1-203.
- , (1968b) A taxonomic study of hylid frogs of the *Hyla lesueuri* complex occurring in North-Western Australia. *Rec. S. Aust. Mus.* 15(4), 711-727.
- , (1971) The phylogenetic significance of vocal sac structure in hylid frogs. *Univ. Kansas Mus. Nat. Hist. Publ.* 19(4), 319-360.
- , (1977) "Frogs of South Australia." 2nd Edition (South Australian Museum: Adelaide).
- (1978) "Amphibians of South Australia." (Govt Printer: Adelaide.)
- , CROOK, G. A. & DAVIES, M. (1983) Reproductive biology of the frogs of the Magela Creek System, Northern Territory. *Rec. S. Aust. Mus.* 18(18), 415-440.
- & DAVIES, M. (1978) Species groups in the Australopapuan hylid frog genus *Litoria* Tschudi. *Aust. J. Zool. Suppl. Ser.* (63), 1-47.

MORPHOLOGY, SYSTEMATICS AND ECOLOGY OF NEW MONOGONONT ROTIFERA (ROTATORIA) FROM THE ALLIGATOR RIVERS REGION, NORTHERN TERRITORY

BY W. KOSTE & R. J. SHIEL

Summary

Seventy-six rotifer taxa were recorded from eight billabongs of the Magela creek, a tributary of the East Alligator River, at the end of a six month dry season. Three new taxa are described and figured: *Brachionus falcatus* Zacharias f. *reductus* n.f., *B. urceolaris sericus* n.f. and *Macrochaetus danneeli* n.sp., with two new records for the continent. The species assemblage is compared to that of the same biotopes in the wet season, in which 174 taxa, including four new species and 25 new records, were identified. Differences in rotifer species assemblages are related to biotope heterogeneity; shallow floodplain billabongs are extreme biotopes with low species diversity, whereas deeper perennial channel billabongs are refuges for a diverse assemblage of periphytic taxa and resting eggs of monogonont and encysted eggs of bdelloid rotifers of ephemeral waters of the area.

MORPHOLOGY, SYSTEMATICS AND ECOLOGY OF NEW MONOGONONT ROTIFERA (ROTATORIA) FROM THE ALLIGATOR RIVERS REGION, NORTHERN TERRITORY

by W. KOSTE* & R. J. SHIEL†

Summary

KOSTE, W. & SHIEL, R. J. (1983) Morphology, systematics and ecology of new monogonont Rotifera (Rotatoria) from the Alligator Rivers region, Northern Territory. *Trans. R. Soc. S. Aust.* **107**(2), 109-121, 31 May, 1983

Seventy-six rotifer taxa were recorded from eight billabongs of the Magela creek, a tributary of the East Alligator River, at the end of a six month dry season. Three new taxa are described and figured: *Brachionus fulcanus* Zacharias f. *reductus* n.f., *B. unicoloris* sericus n.f. and *Macrochaetus danneelfi* n.sp., with two new records for the continent. The species assemblage is compared to that of the same biotopes in the wet season, in which 124 taxa, including four new species and 25 new records, were identified. Differences in rotifer species assemblages are related to biotope heterogeneity; shallow floodplain billabongs are extreme biotopes with low species diversity, whereas deeper perennial channel billabongs are refuges for a diverse assemblage of periphytic taxa and resting eggs of monogonont and encysted eggs of bdelloid rotifers of ephemeral waters of the area.

KEY WORDS: New Rotifera, billabongs, extreme biotopes, northern Australia.

Introduction

The Magela Creek, approximately 260 km east of Darwin (Fig. 1), is an ephemeral tributary of the East Alligator River. It rises on the northern escarpment of the Arnhem Land sandstone plateau and flows northward to join the East Alligator some 90 km from its mouth into Van Diemen Gulf. On its course it passes two uranium ore deposits, Ranger and Jabiruka.

Intensive limnological monitoring prior to commencement of mining operations included studies of billabongs along the Magela Creek downstream of these deposits (e.g. Tait 1979¹, Walker & Tyler 1979², Bishop 1980, Hart & McGregor 1980, Ling & Tyler 1980³, Bishop et al. 1981⁴, Tait 1981, Marchant 1982, Burgman & Tait in press).

In the six month period when most of the Magela Creek floodplain and the channel of the Creek (with the exception of deeper billa-

bongs) dries out, aquatic life is crowded into a few perennial waters. These concentrations of organisms are accompanied by stresses on the system produced by accumulation of organic matter resulting from decomposition. Both vary the water quality so much that individual billabongs can be considered extreme biotopes. The potential exists for further stresses to be placed on these habitats by the development of uranium mining and milling, and associated industrial and domestic wastes entering the Magela Creek system.

A preliminary report on the microcrustacean zooplankton of one of these naturally stressed systems was given by Tait (1981). The only information on the Rotifera (Aschelminthes: Rotatoria) of the Northern Territory are brief notes (Shiel & Koste 1979, Koste & Shiel 1980b) and a more comprehensive paper by Koste (1981). The last publication involved a sample series collected from billabongs of the Magela Creek by R. D. Tait at the end of the wet season (April 1980). This paper gives the results of further studies of samples from the same biotopes collected by Tait at the end of the dry season (Nov.-Dec. 1980), when an

* Ludwig-Brill-Strasse 5, Quakenbrück, D-4570, W. Germany

† Department of Botany, University of Adelaide. Present address: Department of Biology, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1.

¹ Tait, R. D. (1979) Distribution and chemical composition of aquatic macrophytes of the Magela Creek floodplain, Northern Territory. Report presented to Aust. Soc. Limnol. Annual Conference, Tallangatta.

² Walker, T. D. & Tyler, P. A. (1979) *A limnological survey of the Magela system, Alligator Rivers region, Northern Territory*. Interim report to the Office of the Supervising Scientist, Sydney.

³ Ling, H. D. & Tyler, P. A. (1980) *Freshwater algae of the Alligator Rivers region, Northern Territory of Australia*. Report to the Office of the Supervising Scientist, Sydney.

⁴ Bishop, K. A., Allan, S. A., Pollard, D. A. & Cook, M. G. (1981). *Ecological studies on freshwater fish of the Alligator Rivers region, Northern Territory*. Report to the Office of the Supervising Scientist, Sydney.

impoverished rotifer species assemblage was expected. More detailed seasonal data, including systematics and ecology of the microcrustacean plankton, will be published elsewhere (Tait, Shiel & Koste in press.).

Methods and materials

Thirteen plankton samples (25 ml filtrate) were collected from eight billabongs (Table 1) by net tow on 10.11 and 8.12.1980 by R. D. Tait (then of Pancontinental Mining Ltd) and preserved in formalin. Collections were taken from the same billabong series as described by Koste (1981) and included all three types distinguished by Hart & McGregor (1980), i.e. backflow (Winmurra), channel (Buffalo and Island) and floodplain (Ja Ja, Jabiluka, Nankeen, Leichhardt and Mine Valley). Comparative physio-chemical features are tabulated by Koste (1981).

Several samples contained large numbers of microcrustacea. These were removed with a 300 μ m bronze mesh. Microcrustacean assemblages of the billabongs are considered by Tait et al. (in press). Rotifera recorded are listed systematically (following Koste 1978). Several illoricate rotifers, mostly bdelloids, were strongly contracted in response to the preservative, and could not be identified (shown as "indet." in Table 2. For the treatment of samples and individuals, also preparation of trophi, see Koste 1978:42-43 and Koste 1981: 101.

Rotifera new to Australia

Previously unknown rotifers were recorded from Winmurra billabong (*Brachionus falcatus* Zacharias n.f.) Mine Valley billabong (*B. urceolaris sericus* (Rousselet) n.f.) and Buffalo billabong (*Macrochaetus danneeli* n.sp.), described below. Three species, (*Beauchampiella eudaetylota* (Gosse), *Eosphora* cf. *thoides* Wulfert and *Octotrocha speciosa* Thorpe) were recorded for the first time from

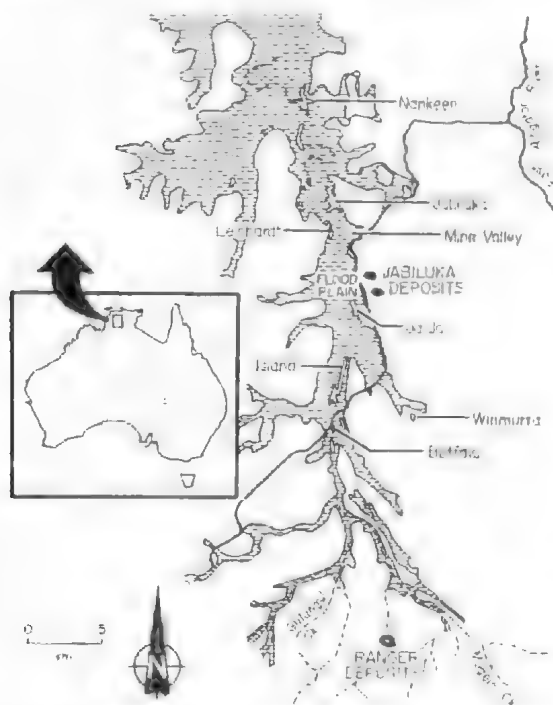


Fig. 1. The Magela Creek floodplain showing billabongs sampled.

Species recorded from each habitat are listed, and seasonal differences in the species assemblages related to environmental fluctuations. Three previously unknown rotifera taxa are described.

TABLE 1. Comparative physico-chemical features at the time of plankton sampling in 8 billabongs of the Magela Creek, at the beginning of the wet season.

Sample No. and date	Billabong	pH	Conductivity μ S cm ⁻²	Water temp. °C	Dissolved O ₂ ppm	cf. April 1980
10.11.80						
1a 80111001	Nanneen	4.47	281	29.1	3.75	pH 5.47
2a 80111002	Jabiluka	4.77	181	31.3	4.15	pH 5.26
3a 80111003	Mine Valley	3.45	931	29.6	5.90	pH 5.37
4a 80111004	Ja Ja	4.24	172	35.0	3.29	pH 5.44
5a 80111005	Island	4.93	51	32.0	5.55	
7a 80111007	Buffalo	5.38	29	30.9	4.15	
8a 80111008	Leichhardt	5.74	218	30.4	4.30	
08.12.80						
1b 80120801	Nanneen	4.45	283	29.1	4.63	
2b 80120802	Jabiluka	4.14	199	31.3	5.04	28 μ S
3b 80120803	Mine Valley	3.25	1233	29.3	7.30	27 μ S
4b 80120804	Ja Ja	4.08	215	32.6	5.67	25 μ S
6b 80120806	Winmurra	5.76	103	29.9	3.72	
7b 80120807	Buffalo	5.30	30	31.4	4.48	

TABLE 2. *Rotifera* from Magela Creek samples, with comments on presence and biogeography. cosm. = cosmopolitan; ptr. = pantropical; end. = endemic; 1 = first record from the continent; per. = perennial; n. = not recorded in April sample series. Sample numbers are as in Table 1. (Abundance: — = not recorded; r = individual specimens or rare; f = frequent, more than 5% of recorded rotifers; m = more than 20% of rotifers recorded.)

Taxon		Sample number															
		1a	1b	2a	2b	3a	3b	4a	4b	5a	6b	7a	7b	8a	8b		
Superorder Bdelloida																	
1. <i>Dissotrocha aculeata</i> (Ehrb. 1832)	cosm.; n.	—	—	—	—	—	—	—	—	f	—	—	—	—	—		
2. <i>D. macrostyla</i> (Ehrb. 1838)	cosm.; n.	—	—	—	—	—	—	—	—	r	—	r	r	—	—		
3. <i>Bdelloida</i> (indet.) (Genera: <i>Philodina</i> , <i>Rotaria</i> , <i>Macrotrachela</i> , <i>Habrotrocha</i>)																	
Superorder Monogononta																	
Order Ploimidae																	
Family Epiphanidae																	
4. <i>Epiphanes clavulata</i> (Ehrb. 1832)	ptr.; per.	—	—	—	—	—	—	—	—	—	f	—	—	—	m		
Family Brachionidae																	
5. <i>Platytas quadricornis</i> (Ehrb 1832)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
6. <i>Brachionus angularis</i> Gosse 1851																	
7. <i>B. bidentata testudinarius</i> (Jakubski 1912)																	
8. <i>B. budapestinensis</i> (Daday 1885)	cosm.; n.	—	—	—	—	—	—	—	—	f	—	m	r	f	—		
9. <i>B. dichotomus dichotomus</i> Shephard 1911	end.; per.	—	—	—	—	—	—	—	—	f	—	—	—	—	—		
10. <i>B. dichotomus reductus</i> Koste & Shiel 1980	end.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
11. <i>B. falcatus falcatus</i> Zacharias 1898	cosm.; per.	—	—	r	—	r	—	r	r	f	—	f	m	—	—		
12. <i>B. falcatus</i> Zach. f. <i>reductus</i> n.f.	end. 1; n.	—	—	—	—	—	—	—	—	f	—	—	—	—	—		
13. <i>B. tyratus</i> Shephard 1911	end.; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
14. <i>B. quadridentatus melheni</i> (Barrois & Daday 1894)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
15. <i>B. urceolaris sericus</i> (Rousselet 1907) n.f.	end.?; n.	—	—	—	—	m	m	—	—	—	—	—	—	—	—		
16. <i>Beauchampiella eudactylota</i> (Gosse 1886)	cosm. 1; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
17. <i>Anuraeopsis coelata coelata</i> (Beauchamp 1932)	ptr.; per.	—	—	—	—	—	—	r	m	m	—	f	f	—	—		
18. <i>A. navicula</i> Rousselet 1910	ptr.; per.	—	—	—	—	—	—	f	—	r	m	r	r	—	—		
19. <i>Keratella tropica tropica</i> (Apstein 1907)	ptr.; per.	r	r	f	—	r	—	m	f	m	—	r	r	—	—		
Fam. Collurellidae																	
20. <i>Collurella obtusa</i> (Gosse 1886)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
21. <i>Lepadella latusinus latusinus</i> (Hilgendorf 1889)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	—	—	—		
22. <i>L. patella patella</i> (O.F.M. 1786)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
23. <i>L. patella</i> (O.F.M.) n.f.	end.?; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
24. <i>L. rhomboides</i> (s.l.) (Gosse 1886)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
Fam. Lecanidae																	
25. <i>Lecane bulla bulla</i> (Gosse 1851)	cosm.; per.	—	—	—	—	—	—	—	—	f	—	—	r	—	—		
26. <i>L. closterocerca closterocerca</i> (Schmarda 1895)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
27. <i>L. curvicornis curvicornis</i> (Murray 1913)	ptr.; per.	—	—	—	—	—	—	—	—	—	r	r	f	—	—		
28. <i>L. hamata hamata</i> (Stokes 1896)	cosm.; per.	—	—	—	—	—	—	r	r	—	—	—	r	—	—		
29. <i>L. doryssa</i> (Harring 1914)	ptr.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
30. <i>L. ludwigi</i> (s.l.) (Eckstein 1893)	cosm.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
31. <i>L. papuana</i> (Murray 1913)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
32. <i>L. pyriformis</i> (Daday 1905)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
33. <i>L. quadridentata</i> (Ehrb. 1832)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
34. <i>L. scutata</i> (Harring & Myers 1926)	cosm.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
35. <i>L. signifera signifera</i> (Jennings 1896)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	r	r	—	—		
36. <i>L. signifera ploenensis</i> (Voigt 1902)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	r	—		
37. <i>L. tenuiseta</i> Harring 1914	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
38. <i>L. inopinata</i> (Harring & Myers 1926)	ptr.; per.	—	—	—	—	—	—	—	—	—	—	—	r	r	—		
Fam. Euchlanidae																	

Taxon		Sample number															
		1a	1b	2a	2b	3a	3b	4a	4b	5a	6b	7a	7b	8a	8b		
39. <i>Diplechlanis propatula macrodactyla</i> (Hauer 1965)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
Fam. Trichotridae																	
40. <i>Macrochaetus collinsi</i> (Gosse 1867)	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
41. <i>M. danneeli</i> n. sp.	end.?, 1; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
Fam. Notommatidae																	
42. <i>Scaridium longicaudum</i> (O.F.M. 1786)	cosm.; per.	—	—	—	—	—	—	—	—	r	—	—	r	—	—		
43. <i>Monommata grandis</i> Tessin 1890	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
44. <i>M.</i> indet. (diff. sp.?)		—	—	—	—	—	—	—	—	r	—	—	—	—	—		
45. <i>Taphrocampa selenura</i> (Gosse 1887)	cosm.; per.	—	—	—	—	—	—	r	—	r	—	—	r	—	—		
46. <i>Notommata copeus</i> Ehrb. 1834	cosm.; per.	—	—	—	—	—	—	—	—	—	—	r	—	—	—		
47. <i>N.</i> indet. (diff. sp.?)		—	—	—	—	—	—	—	—	r	—	r	r	—	—		
48. <i>Resticula melandocus</i> (Gosse 1887)	cosm.; n.	—	—	—	—	—	—	—	—	—	—	r	—	—	—		
49. <i>Eosphora</i> cf. <i>thoides</i> Wulfert 1935	cosm. 1; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
50. <i>Cephalodella gibba gibba</i> (Ehrb. 1832)	cosm.; per.	—	—	—	—	—	—	—	—	r	r	—	—	—	—		
51. <i>C. tinca</i> Wulfert 1937	cosm.; n.	—	—	—	—	—	—	—	—	—	r	—	—	—	—		
52. <i>C.</i> indet. (diff. sp.?)		—	—	—	—	—	—	—	—	—	—	—	—	—	—		
Fam. Trichocercidae																	
53. <i>Trichocerca chattoni</i> De Beauchamp 1907	ptr.; per.	—	—	—	—	—	—	—	—	f	—	—	—	r	—		
54. <i>T. longiseta</i> (Schränk 1802)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
55. <i>T. pusilla</i> (Lauterborn 1898)	cosm.; per.	—	—	—	—	—	—	r	—	—	r	r	r	—	—		
56. <i>T. similis similis</i> (Wierzejski 1893)	cosm.; per.	—	—	—	—	—	—	—	—	m	r	m	m	—	—		
57. <i>T. stylata</i> (Gosse 1851)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	r	r	—	—		
Fam. Gastropodidae																	
58. <i>Ascomorpha saltans saltans</i> Bartsch 1870	cosm.; n.	—	—	—	—	—	—	—	—	—	—	f	f	—	—		
Fam. Synchaetidae																	
59. <i>Synchaeta</i> cf. <i>longipes</i> Gosse 1887	cosm.; per.	—	—	—	—	—	—	—	—	—	—	f	r	—	—		
60. <i>Polyarthra</i> cf. <i>vulgaris</i> Carlin 1943	cosm.; per.	—	—	—	—	f	f	r	r	f	f	f	f	r	—		
Fam. Asplanchnidae																	
61. <i>Asplanchna sieholdi</i> (Leydig 1854)	cosm.; per.	—	—	r	—	—	—	—	—	r	—	r	r	—	r		
Fam. Diceranophoridae																	
62. <i>Diceranophorus claviger australiensis</i> Koste & Shiel 1980	end.; per.	—	—	—	—	—	—	—	—	—	r	r	r	—	—		
63. <i>D. grandis</i> (Ehrb. 1832)	cosm.; n.	—	—	—	—	—	—	—	—	—	—	r	—	—	—		
Order Gnesiotrocha																	
Fam. Testudinellidae																	
64. <i>Testudinella patina patina</i> (Hermann 1783)	cosm.; per.	—	—	—	—	—	—	—	—	r	—	r	r	—	—		
65. <i>T. tridentata tridentata</i> Smirnov 1931	ptr.; per.	—	—	—	—	—	—	—	—	r	—	r	r	—	—		
Fam. Floscularidae																	
66. <i>Laciniaria flosculosa</i> (O.F.M. 1758)	cosm.; per.	—	—	—	—	—	—	—	—	—	r	—	r	—	—		
67. <i>Octotrocha speciosa</i> Thorpe 1893	ptr., 1; n.	—	—	—	—	—	—	—	—	—	—	—	r	—	—		
Fam. Conochilidae																	
68. <i>Conochilus dossuarius</i> (Hudson 1895)	ptr.; per.	—	—	—	—	—	—	—	—	f	—	f	f	r	—		
69. <i>C. unicornis</i> Rousselet 1892	cosm.; n.	—	—	—	—	—	—	—	—	—	—	r	r	—	—		
Fam. Hexarthridae																	
70. <i>Hexarthra intermedia</i> Wiszniewski 1929	cosm.; per.	—	—	—	—	—	—	—	—	—	—	r	f	—	—		
71. <i>H. mira</i> (Hudson 1871)	cosm.; per.	—	—	—	—	—	—	—	—	—	—	—	—	—	r		
Fam. Filiniidae																	
72. <i>Filinia australiensis</i> Koste 1980	end.; per.	—	—	—	—	—	—	—	—	f	—	—	—	—	—		
73. <i>F. longiseta limnetica</i> (Zacharias 1893)	cosm.; n.	—	—	—	—	—	—	—	—	r	—	—	—	—	—		
74. <i>F. opoliensis</i> (Zacharias 1898)	ptr.; per.	—	—	—	—	—	—	r	m	f	f	—	—	—	r		
75. <i>F. passa</i> (O.F.M. 1786)	cosm.; n.	—	—	—	—	—	—	—	—	—	f	—	—	—	—		
76. <i>F. pejeri</i> Hutchinson 1964	ptr.; per.	—	—	—	—	—	—	—	—	r	—	—	—	—	—		
Total species		1	1	3	0	4	2	9	11	33	16	29	56	3	5		

Australia. These six, with four new species and 25 new records listed by Koste (1981), bring the Rotifera recorded from the continent to 477 (Koste 1978, 1979, 1980, 1981; Shiel & Koste 1979; Koste & Shiel 1980a,b; Green 1981).

Systematic descriptions

Brachionus falcatus Zacharias 1898 f.
reductus n.f.

FIGS 2a,b; 3e

Material: More than 100 contracted females, some with subitaneous eggs; single population of uniform lorica form, sample 80120406. **Type locality:** Winnurra billabong on the eastern margin of the Magela Creek Valley, N.T. (Fig. 1), 132°53'20", 12°31'41"S.

Holotype: Loricata female coll. R. D. Tait 8.12.1980, in type collection Zoological Museum, Christian Albrechts University, Kiel D-2300 FRG. Reg. no. 84.

Paratype: In W. Koste collection, *Brachionus*. Date and locality as holotype. See photomicrograph Fig. 2a-b.

Description: Very robust lorica of barrel-shaped outline. Anterior-, marginal- and medial spines as in type form. Submedial spines shortened in proportion to lorica. Caudal spines shortened but strongly developed. Surface of dorsal lorica (Fig. 2a) with pearl-like structures. Pair of ridges begin at basis of submedial spines, run to height of lateral antennae. Ventral lorica (Fig. 2b) flat and strong, detailed with a granulated pattern. Male not recorded.

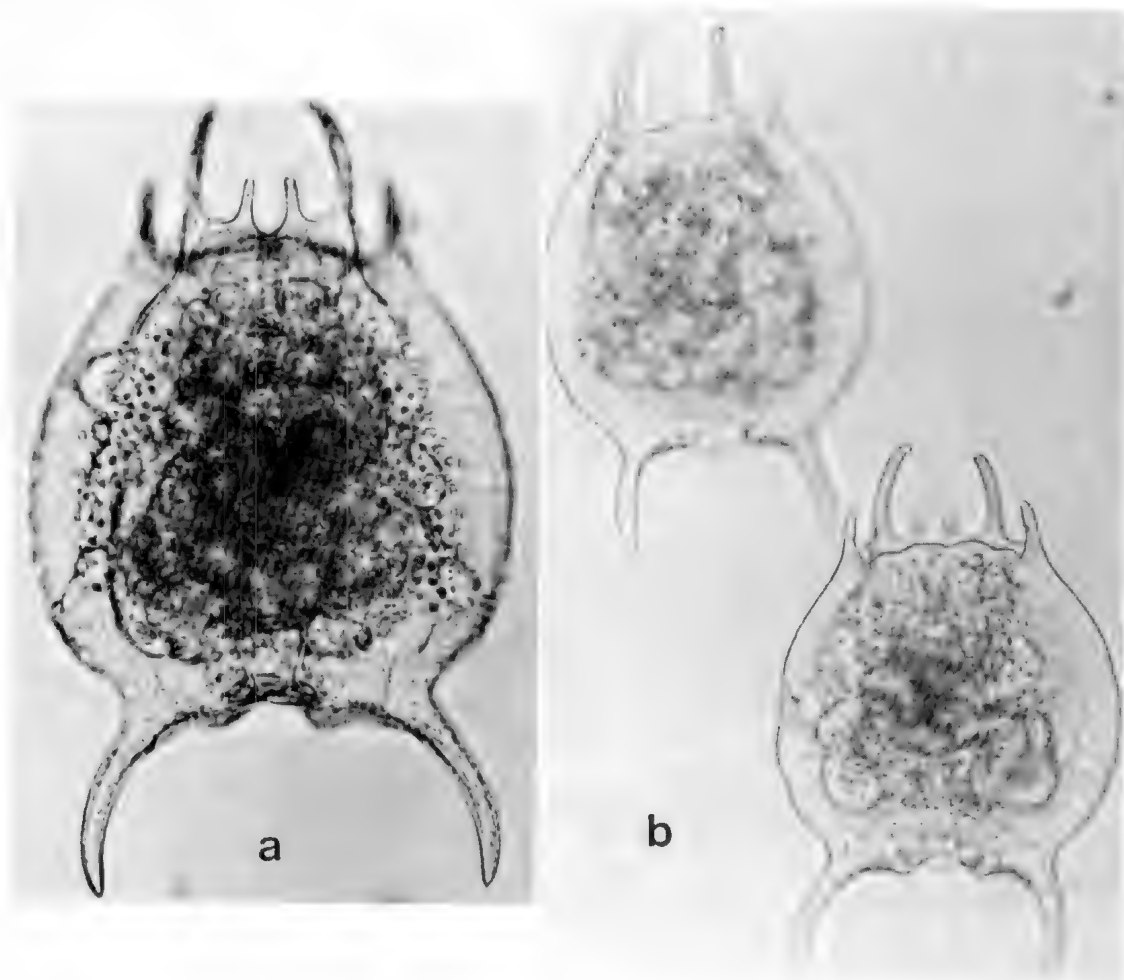


Fig. 2. a. *Brachionus falcatus* Zach. f. *reductus* showing large granules on the dorsal lorica. b. *B. falcatus* f. *reductus*, lorica, ventral view.

Measurements: Lorica length 100–280 μm , including anterior and posterior spines; lorica width 80–164 μm ; subitaneous egg 80 \times 60 μm to 100 \times 72 μm .

Discussion: This pantropical and pansub-tropical species (Ahlstrom 1940) shows little variability in its habit (Weber 1906, Chengalath *et al.* 1973, Pejler 1977, Koste 1978). It

is occasionally encountered in summer warmed eutrophic biotopes in Europe, particularly in Romania and the Caucasus. In Australia, *B. falcatus* f. typ. was reported from Queensland by Colledge (1909). Koste & Shiel (1980), after a study of rotifer taxocenes in southern Australia, determined positive regional types with regard to lorica surface morphology (see also Figs. 3a–f).

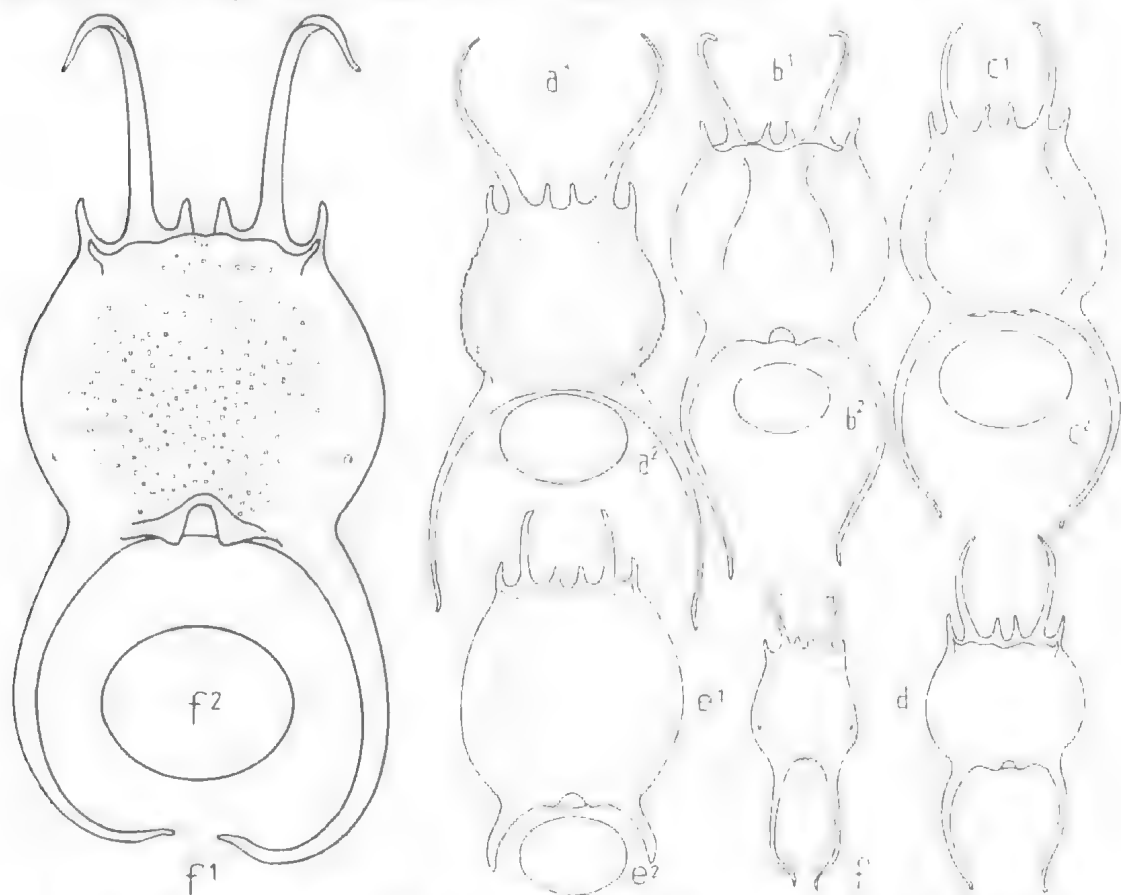


Fig. 3. *Brachionus falcatus* Zacharias 1898: various lorica forms. a¹–c¹: from Ja Ja billabong, lorica length 330–400 μm ; a²: subitaneous egg 100 \times 70 μm ; b²: male egg 72 \times 52 μm ; c²: subitaneous egg 100 \times 72 μm ; d: from Buffalo billabong, lorica length 260 μm , juvenile form; e¹: f. *reductus* n.l. from Winmurra billabong, lorica length 280 μm , lorica width 164 μm ; e²: subitaneous egg 80 \times 60 μm ; f: slender form from Malacca, S.E. Asia. Lorica length 335 μm , lorica width 160 μm ; f¹: large form from River Murray, S. Aust. Lorica length 492 μm , lorica width 280 μm ; f²: subitaneous egg, 108 \times 90 μm .

In populations studied earlier, juveniles occasionally were observed with shortened caudal spines (Fig. 3d). This apparently is due to allometric growth. Adult animals encountered in billabongs of the Magela Creek, however, mostly had curved postero-lateral spines exceeding body length. Only in Winmurra billabong was there a sparse population

of individuals with uniformly robust, strongly shortened posterior spines. This morph is previously unknown. (Ahlstrom 1940: Fig. 10: 1–2; Voigt 1957: Fig. 21:10a–11; Sudzuki 1964: Fig. 9:1–7; Chengalath *et al.* 1973, Figs 24–26; Koste 1978: Fig. 14.2).

The reason for the reduction in terminal spines could not be established. Low oxygen

levels in the biotope are noteworthy (3.72 mg O₂ 1⁻¹).

Brachionus urceolaris sericus (Rousselet 1907)
n.f.

FIGS 4-6

Material: Two samples (80120803, 80111003) of 25 ml from the same locality with many females, all age classes with uniform loricas, many subitaneous eggs, large population.

Type locality: Mine Valley Billabong, Magela Creek near Jabiluka, N.T. 132°53'06"E/12°29'54"S (Fig. 1). Extreme biotope. Figs 4a, b.

Holotype: Lorica, single adult female from sample 80120803 coll. R. D. Tait 8.12.1980. Trophi preparation deposited in type collection, Zoological Museum, Christian Albrechts University, Kiel, D-2300 F.R.G., Reg. no. 85.

Paratype: Data as for holotype, Reg. no. 86.

Description: Lorica of heraldic outline without lateral posterior spines and with short anterior spines, median of which is a little longer. Dorsal lorica short, ventral lorica caudally tapering. Foot opening without protruding tube, ventral arch egg shaped, caudal trapezoid. Ventral anterior lorica margin plain,

upper dorsal lorica with two stout ribs beginning between median and submedian spines and running in direction of periphery. Submedian spines reinforced with short cuticular outer borders. Lorica surface and foot opening reinforced dorsally, weaker ventrally and covered with granular structures. In lateral view, caudal lorica margin occasionally appears two-stage, elevated by sharp edge from narrow platelike base of foot tube opening. In dorsal view, two convex lines appear over foot tube, define boundary beneath dorsal lorica.

Measurements: Lorica length 120-220 μ m, lorica width 80-172 μ m. Foot opening ventral 52 μ m high \times 40 μ m wide, dorsal 12 μ m high \times 15 μ m wide.

Discussion: The lorica outline of the new *B. urceolaris sericus* form, with an elevated caudal section, resembles that of *B. quadridentatus* forms from the literature. In particular, *B. quadridentatus* var. *ancylognathus* (Schmarda 1859) and *B. quadridentatus* var. *cluniorbicularis* Skorikow 1884. The lorica surface of this distinctive polymorph, as in the *quadridentatus* species group, is granulated and dimpled, with tiny ridges present. Nevertheless, *urceolaris* and *quadridentatus* taxa are

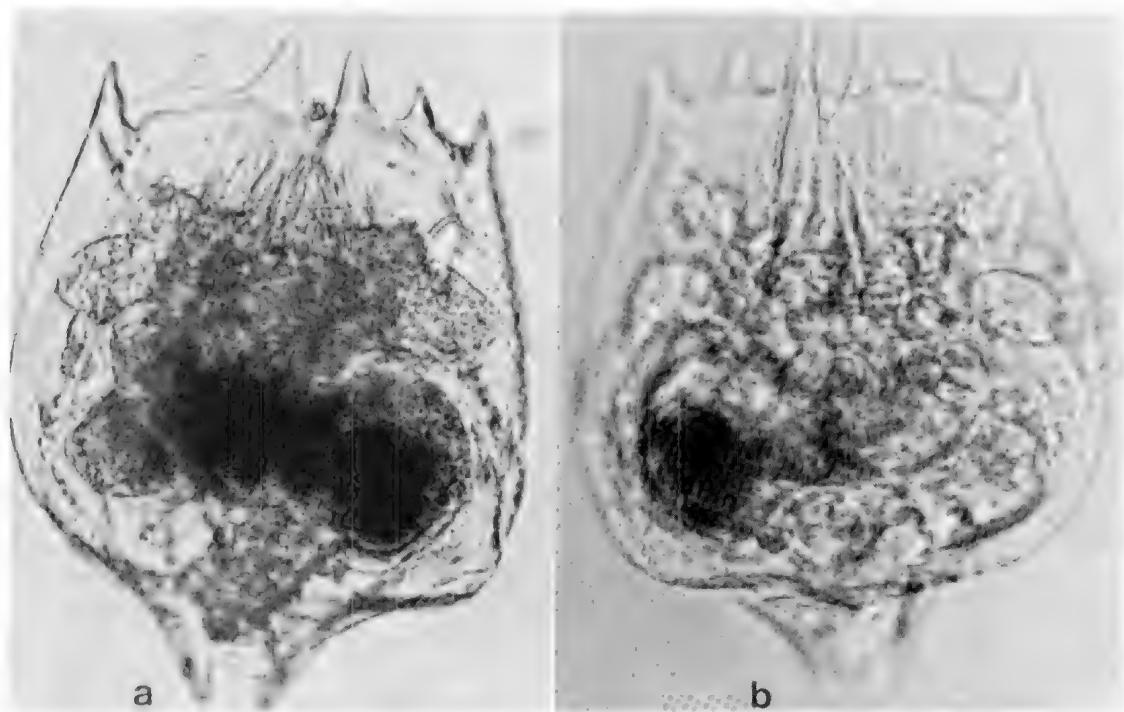


Fig. 4. *Brachionus urceolaris sericus* (Rousselet 1907) n.f. a: lorica, dorsal; b: lorica, ventral.

readily distinguished; the latter always has a projecting foot tube, whereas the former (Figs 5–6) has only a flat foot opening incised at the end of the ventral plate. Therefore, this taxon from northern Australia is considered a *Brachionus urceolaris* form of the subspecies *sericus* (Fig. 6a) after Hauer (1963) from *B. urceolaris* f. *sericus* (Rousselet 1907). This was previously described, however, with a more or less strongly pleated lorica surface, as in the type. See also Sladeczek (1955) and Koste (1968). Hauer (1963) records morphs from Egypt, Sweden and Germany. We concluded that these forms of the species *B. urceolaris* (O.F. Muller 1776) (Fig. 6b) are produced in response to the chemistry of the respective habitats. A lorica surface as present in the new form of *B. urceolaris sericus* has not been described previously. It is characterized through a densely granulated and dimpled, striated surface, particularly pronounced in the caudal section of the lorica (Fig. 4a,b). Similar lorica patterns are seen on animals from small standing waters of the Sahara (Fig. 5a,b).

As for previous records of *B. urceolaris sericus*, the new form occurs in strongly acidified biotopes (pH 3.25–3.45), with greatly compacted and uniform loricas. Whereas *B. urceolaris urceolaris* (O.F.M.) is observed only in habitats with pH ranges of approximately 5.0–11.0, the ssp. *sericus* by comparison, is adapted to extreme biotopes, e.g. sulphate lakes, which are more strongly acidified (pH 2.8–4.0). It is commonly the only rotifer species in these habitats, apart from isolated incursion species of other taxa, to develop and maintain large populations. Both the type and ssp. are cosmopolitan.

Machrochaetus dannecli n.sp.

FIGS 7, 9

Material: Two contracted females from sample 8011107.

Type locality: Buffalo billabong, Magela Creek valley, 132°52'40"E; 12°34'55", south of Jabiluka, N.T. (Fig. 1).

Holotype: Female with contracted head (Fig. 7a–b); trophi preparation in glycerine with Caedex inclusion, deposited in type collection Zoological Museum, Christian Albrechts University, Kiel, FRG. Reg. no. 87.

Paratype: Lost in preparation. See Iconoparatype Fig. 7.

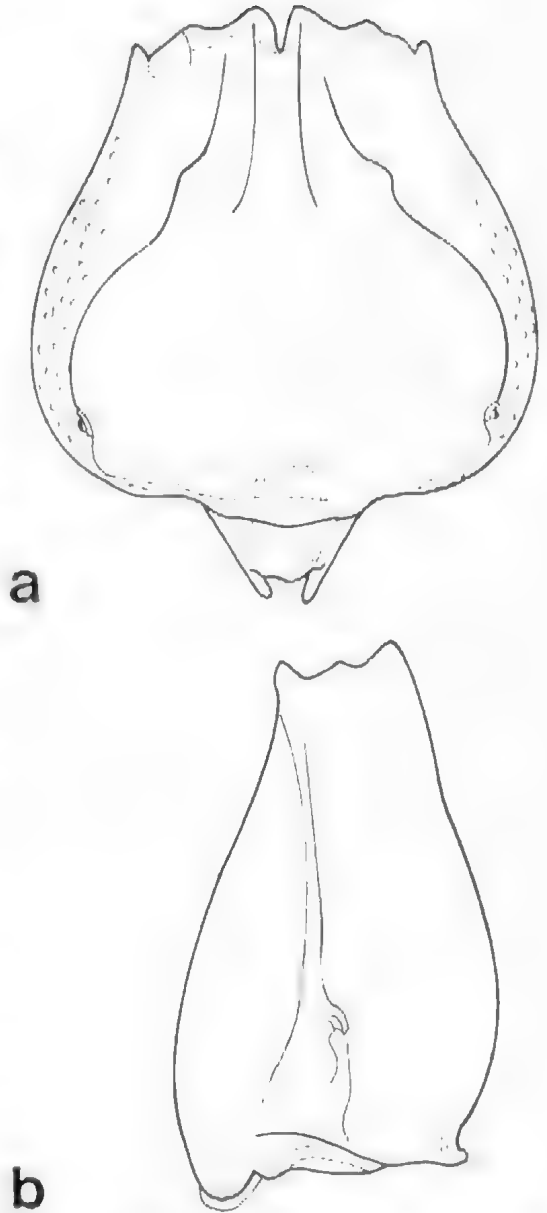


Fig. 5. *Brachionus urceolaris sericus* f. *africana*. a: lorica, dorsal; b: lorica lateral.

Description: Lorica covered with pustules and granules. Body with usual cross section (Fig. 9h), egg with elliptical outline. Anal segment spineless. Dorsal lorica with terraced sides to blunt keel. Margin of keel base with longer spinules, terraced rim wider at start, tapering caudally; uppermost keel dorsum covered with large cuticular ledges and beading. Shoulder spines, posterolateral-, postmedian- and only one pair of rudimentary anterosubmedian

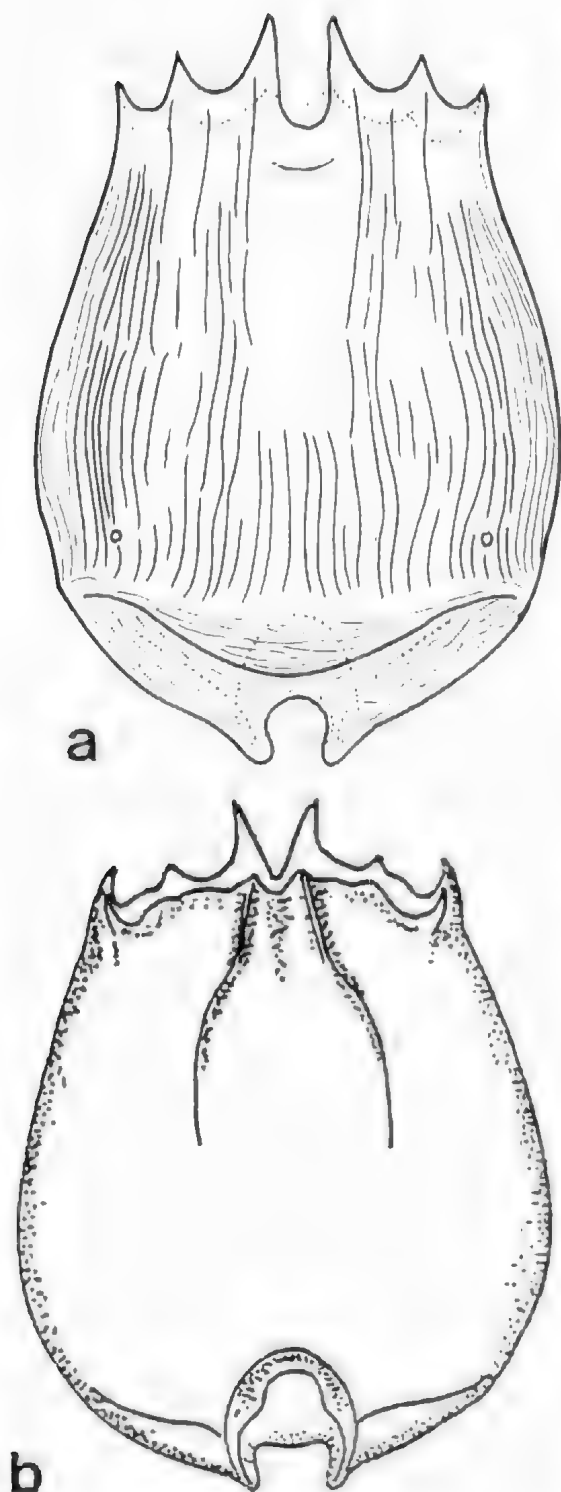


Fig. 6. a: *Brachionus urceolaris sericeus* (Rousselet 1907), b: f. typica from N.W. Germany.

spines present (3a-b, Fig. 9a). Lateral antennae project from strong three stepped cylindrical pyramid. Ventral lorica with blunt keel and shallow curved, wide foot opening. Foot bi-articulated; toes short, spindle-formed. *Measurements*: Lorica length 125–130 μm , lorica width 130–137 μm . Foot segment 20 μm , toe length 16–18 μm .

Discussion: The important taxonomic morphological characteristic of *Macrochaetus* Perty is the number of spines and longer spinules (see Wulfert 1964 and Koste 1978). Their total number (Fig. 9a) ranges from 8 (without shoulder spines, Fig. 8a-h, cf. Fig. 8, *M. sericeus* (Thorpe 1893)) to 16 (cf. for example Fig. 10, *M. multispinosus* Myers 1934). Of the possible insertion points of the dorsal spines in the taxon described here, only 2a-b and 6a-b are occupied. Shoulder hooks and short posteroventral spines are present. The deeply extended spine-free anal segment (Fig. 7b) is, moreover, noteworthy. A *Macrochaetus* with this morphological characteristic is hitherto unknown.

Etymology: This new species is dedicated to Prof. Dr Ilse Danneel, University of Duisburg.

General ecological features

As shown in Table 3, only 76 taxa were recorded from the 13 Nov.-Dec. samples, whereas 174 were identified from samples collected in April (cf. Koste 1981). Of the 76 recorded taxa, 40 are cosmopolitan, 15 pantropical or pansubtropical, seven probably endemic, 53 perennial. There were 16 new records for the biotope, four new records for Australia, and 12 indeterminate taxa.

Table 3 shows also that the deep billabongs of the Mudginberri corridor (Buffalo, Island) supported a species rich rotifer taxocene in spite of the onset of the dry, with increased conductivity and acidity. The floodplain billabongs (Nankeen, Mine Valley, Leichhardt) had a depauperate fauna or were free of rotifers (Jabiluka). Some of the latter biotopes, as a result of strongly acid conditions (Mine Valley pH 3.25–3.45, Ja-Ja pH 4.08–4.24, Jabiluka pH 4.14–4.77), can be considered extreme biotopes. In addition to incursion species with low abundance, very dense populations of fugitive species developed in some of these, e.g. *B. urceolaris sericeus* in Mine Valley. Overall, mass populations (over 20% of the respective species present) were recorded for the following taxa: *Brachionus angularis* (Winmurra), *B. budapestiensis*

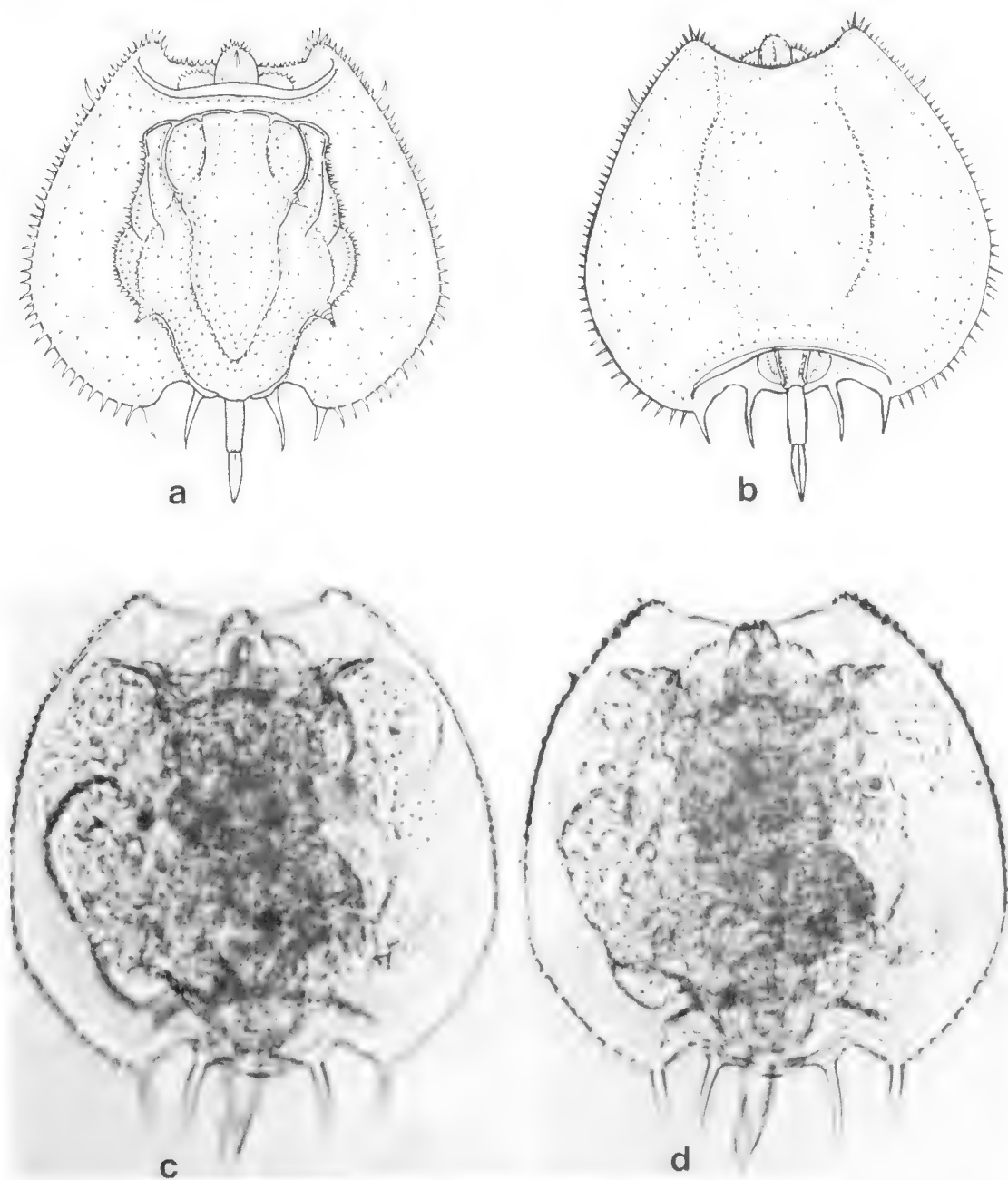


Fig. 7. a: *Macrochaetus danneeli* n. sp., contracted female. Lorica length 130 μm , lorica width 136 μm . b: *M. danneeli* n. sp., contracted female, ventral. c: *M. danneeli*, n. sp., dorsal. d: *M. danneeli*, n. sp., ventral (cf. Fig. 7c).

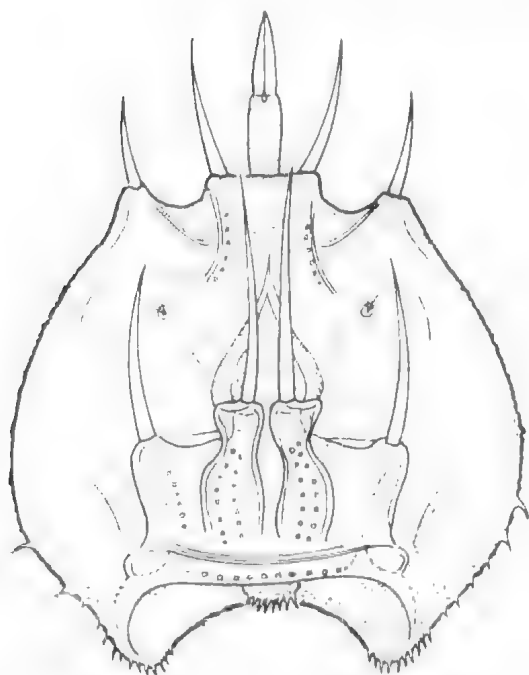


Fig. 8. *Macrochaetus sericus* (Thorpe 1893) dorsal.

(Winmurra), *B. falcatus* (Buffalo), *Epiphanes clavulata* (Leichhardt), *Filinia opoliensis* (Ja Ja), *Keratella tropica* (Ja Ja, Jabiluka, Island) and *Trichocerca similis* (Island, Buffalo). These observations are in accord with those on billabong plankton populations in south eastern Australia, where different species dominants occur even in adjacent billabongs, often in bloom proportions, in both rotiferan and microcrustacean components of the plankton (Shiel 1980, 1981⁴).

Acknowledgments

For collecting material while based at Jabiluka, and for comments on a draft MS, we thank Russell Tait, Rundle Project, Esso Australia Ltd Gladstone, Qld. For identification of copepods, thanks are also due to Prof. W. Kiefer, Institut für Seenforschung und Fischereiwesen (Max-Auerbach-Institut). Assistance provided to WK by the Deutschen Forschungsgemeinschaft is gratefully acknowledged. We thank also Ruth Altmann for Fig. 1, Phil Kempster for photography, Prof. W. D. Williams for word-processing facilities, and Mike Tyler for editorial corrections.

⁴ Shiel, R. I. (1981) Plankton of the Murray-Darling River system, with particular reference to the zooplankton. Ph.D. Thesis. University of Adelaide (unpublished).

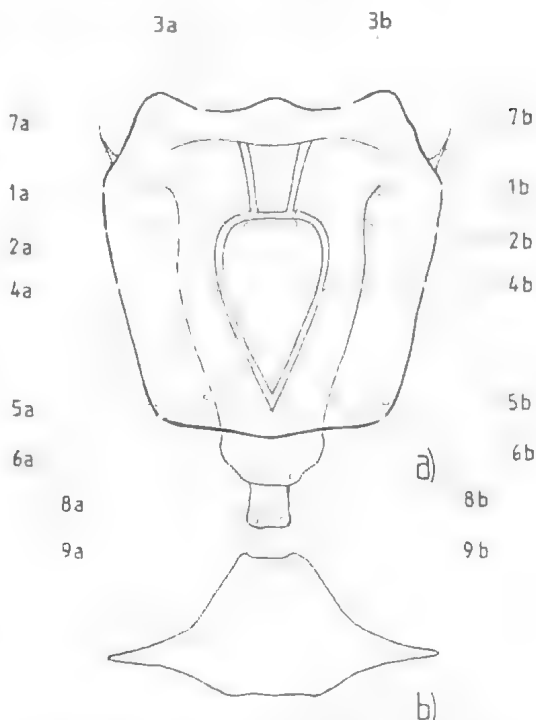


Fig. 9. a. Points of insertion of spines and setules in the genus *Macrochaetus* Perty 1850. 1a-b Anterolateral spines; 2a-b Anterosubmedian spines; 3a-b Anteromedian spines; 4a-b central dorsal spine pair; 5a-b Posterolateral spines; 6a-b Posteromedian spines; 7a-b shoulder hooks; 8a-b Anal segment spines. b. Loric transverse section of a *Macrochaetus*.

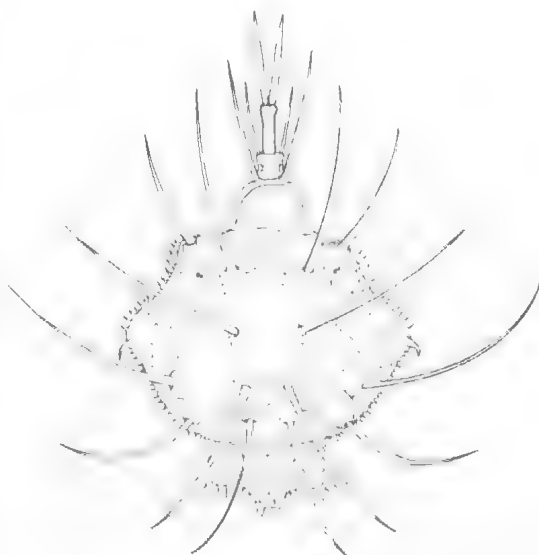


Fig. 10. *Macrochaetus multispinosus* Myers 1934, dorsal (from S. America).

TABLE 3. Comparison of species present in samples from each billabong at the end of wet and end of dry seasons.

Billabong	End of wet season		End of dry season	
Nankeen	15.06.79	15.04.80	10.11.80	08.12.80
01	29	28	1	1
Jabiluka	13.06.79	15.04.80	10.11.80	08.12.80
02	24	36	3	0
Mine Valley	13.06.79	15.04.80	10.11.80	08.12.80
03	67	36	4	2
Ja Ja	13.06.79	15.04.80	10.11.80	08.12.80
04	35	28	9	11
Island	14.06.79	15.04.80	10.11.80	08.12.80
05	21	40	33	n.a.
Winmurra	14.06.79	15.04.80	10.11.80	08.12.80
06	36	61	n.a.	16
Buffalo	14.06.79	15.04.80	11.11.80	08.12.80
07	26	41	29	56
Leichhardt	13.06.79	15.04.80	11.11.80	08.12.80
08	19	55	3	5

References

- AHLSTROM, E. H. (1940) A revision of the rotatorian genera *Brachionus* and *Platyas* with descriptions of one new species and two new varieties. *Am. Mus. Nat. Hist.* **77**(3), 148-84.
- BISHOP, K. A. (1980) Fish kills in relation to physical and chemical changes in Magela Creek (East Alligator River system, Northern Territory) at the beginning of the tropical wet season. *Aust. Zool.* **20**(3), 485-500.
- BURGMAN, M. A. & TAIR, R. D. (in press) Phytoplankton of the Magela Creek, Northern Territory. *Aust. J. Mar. Freshwat. Res.*
- & — (in press) Ecology of the phytoplankton of the Magela Creek, Northern Territory. *Ibid.*
- CHENGALATH, R., FERNANDO, C. H. & KOSTE, W. (1973) Rotifera from Sri Lanka (Ceylon) 2. Further studies on the Eurotatoria including new records. *Bull. Fish. Res. Stn, Sri Lanka* **24**, 29-62.
- COLLEDGE, W. R. (1909) Lecture on Brisbane pond life. *Proc. R. Soc. Qld* **22**(1), 35.
- GREEN, J. (1981) Associations of rotifers in Australian crater lakes. *J. Zool.* **193**, 469-86.
- HART, B. T. & MCGREGOR, R. J. (1980) Limnological survey of eight billabongs in the Magela Creek catchment, Northern Territory. *Aust. J. Mar. Freshwat. Res.* **31**, 611-26.
- HAEUER, J. (1963) Zur Kenntnis der Radertiere (Rotatoria) von Agypten. *Arch. Hydrobiol.* **59**(2), 162-95.
- KOSTE, W. (1968) Über die Rotatorienfauna des Naturschutzgebietes "Achmer Grasmoor", Kreis Bersenbrück. *Veroff Naturw. Ver. Osnabrück*, **32**, 106-60.
- (1978) *Rotatoria. Die Radertiere Mitteleuropas. Ueberordnung Monogononta*, 2 Vols. Revision of M. Voigt. Borntraeger, Berlin.
- (1979) New Rotifera from the River Murray, south-eastern Australia, with a review of the Australian species of *Brachionus* and *Keratella*. *Aust. J. Mar. Freshwat. Res.* **30**, 237-57.
- (1980) Über zwei Plankton-Radertiergattungen *Filinia australiensis* n.sp. und *Filinia hoffmanni* n.sp., mit Bemerkungen zur Taxonomie der *longiseta/terminalis* Gruppe, Genus *Filinia* Bory de St Vincent, 1824, Familie Filiniidae Bartos 1959 (Ueberordnung Monogononta). *Arch. Hydrobiol.* **90**(2), 230-56.
- (1981) Zur Morphologie, Systematik und Ökologie von neuen monogonoten Radertieren (Rotatoria) aus dem Überschwemmungsgebiet des Magela Creek in der Alligator River region, Australiens, N.T., Teil 1, *Osnabrücker Naturwiss. Mitt.* **8**, 97-126.
- & SHIEL, R. J. (1980a) On *Brachionus dictyonus* Shephard, 1911 (Rotatoria: Brachionidae) from the Australian region, with a description of a new subspecies. *Proc. R. Soc. Vict.* **91**(2), 127-34.
- & — (1980b) New Rotifera from Australia. *Trans. R. Soc. S. Aust.* **104**(5), 133-44.
- MARCHANT, R. (1982) Seasonal variation in the macroinvertebrate fauna of billabongs along Magela Creek, Northern Territory. *Aust. J. Mar. Freshwat. Res.* **33**, 329-42.
- PELTER, B. (1977) On the global distribution of the family Brachionidae (Rotatoria). *Arch. Hydrobiol. Suppl.* **53**(2), 255-306.
- ROUSSET, C. F. (1907) On *Brachionus sericus*, n.sp., a new variety of *Brachionus quadratus* and remarks on *Brachionus rubens* of Ehrenberg. *J. Quekett Micr. Club. London ser. 2* **10**, 147-54.
- SHIEL, R. J. (1980) Billabongs of the Murray-Darling system. In W. D. Williams (Ed.) *An ecological basis for water resource management* A.N.U. Press, Canberra.
- & KOSTE, W. (1979) Rotifera recorded from Australia. *Trans. R. Soc. S. Aust.* **103**(3), 57-68.
- SEANECEK, V. (1955) The zooplankton of the reservoir Sous with a contribution to the method of its quantitative determinations. *Casopis Nrodumho museu odd. podoved.* **124**(2), 150-60.
- SUZUKI, M. (1964) New systematical approach to the Japanese planktonic Rotatoria. *Hydrobiologia* **23**(1/2), 1-124.

- TAIT, R. D. (1981) Natural seasonal changes in the zooplankton population in a billabong of the Magela Creek, Northern Territory, Australia, prior to development in the area, pp. 29-35 In M. Sudzuki (Ed.) *Some approaches to saprobio-logical problems*. Sanseido, Tokyo.
- , SHIEL, R. J. & KOSTE, W. (in press) Structure and dynamics of zooplankton communities, Alligator Rivers region, N.T., Australia. *Hydrobiologia*.
- VOIGT, M. (1957) *Rotatoria. Die Radertiere Mitteleuropas*. 2 vols. Berlin-Nikolasee.
- WEBER, E. F. (1906) Rotateurs (Voyage du Dr Walter Volz). *Zool. Jahrb. Abt. Sytem.* 24(3), 207-26.
- WULFERT, K. (1964) Unsere gegenwartige Kenntnis der Rotatoriengattung *Macrochaetus*. *Limnologia, Berlin* 2(3), 347-66.
- ZACHARIAS, O. (1898) Untersuchungen über das Plankton der Teichgewässer. *Forsch. Ber. Biol. Stn zu Plon, Stuttgart* 6, 89-139.

A LARGER BIVALVE ARTHROPOD FROM SADME EDEOWIE-1 WELL OF PROBABLE CAMBRIAN AGE

BY P. A. JELL

Summary

A large bivalve arthropod carapace from 494.92 m down SADME Edeowie-1 well situated 7 km northeast of Brachina Siding just west of the Flinders Ranges is described as *Papiliocaris arrugia* gen. et sp. nov. Its age and rock formation are indeterminate but an Early or Middle Cambrian Age is most probable. The distinctive carapace ornament, interpreted as probably having a second respiratory function, may have developed from or into the ornament of *Tuzoia* Walcott but no phylogeny can be established.

A LARGER BIVALVE ARTHROPOD FROM SADME EDEOWIE-1 WELL OF PROBABLE CAMBRIAN AGE

by P. A. JELL*

Summary

Jell, P. A. (1983) A larger bivalve arthropod from SADME Edeowie-1 well of probable Cambrian Age. *Trans. R. Soc. S. Aust.* 107(2), 123-125, 31 May, 1983.

A large bivalve arthropod carapace from 494.92 m down SADME Edeowie-1 well situated 7 km northeast of Brachina Siding just west of the Flinders Ranges is described as *Papilocaris arrugia* gen. et sp. nov. Its age and rock formation are indeterminate but an Early or Middle Cambrian Age is most probable. The distinctive carapace ornament, interpreted as probably having a secondary respiratory function, may have developed from or into the ornament of *Tuzoia* Walcott but no phylogeny can be established.

KEY WORDS: Bivalve, arthropod, Flinders Ranges, Early, Mid Cambrian, new species.

Introduction

Knowledge of large bivalve arthropods from Australian sediments is not extensive (Chapman 1903; Glaessner 1979; Jell 1980; Rolfe 1966) so any new information is significant.

The South Australian Department of Mines & Energy (SADME) Edeowie-1 well, situated 7 km northeast of Brachina Siding at 31°16.7'S, 138°26.6'E on the Parachilna 1:250 000 geological map (Dalgarno & Johnson 1966), in the Pirie-Torrens Basin on the western edge of the Flinders Ranges, produced the single specimen described below.

It was split from the 60 mm core recovered from a depth of 494.92 m below the surface and is contained in a grey-green mudstone. A palynological determination on carbonaceous shale from 333.4–333.5 m down the same well indicated a Late Eocene age so providing an upper limit to the possible age of this fossil.

Determination of the rock unit and age of this fossil is inconclusive but may be inferred with some confidence from circumstantial evidence. The sequence in which the fossil-bearing core occurs in Edeowie-1 well has a gross lithology comparable with the Cambrian Billy Creek Formation, Balcórancana Formation, or Pantapinna Sandstone (lower part of uppermost outcropping part), and it is considered that the sequence is most likely upper Balcórancana Formation or possibly lower (red) Pantapinna Sandstone. Although Precambrian Adelaidean sediments have been reported from drill-holes in the Pirie-Torrens Basin (e.g. in SANTOS Motpene-1, 19 km northwest of Edeowie-1, Dalgarno and John-

son, 1966), the core in Motpene-1 well at least is now considered to resemble Balcórancana Formation more closely¹ (D. I. Gravestock, *in litt.*).

Other large bivalve arthropods (*Isoxys communis* Glaessner 1979 and *Tuzoia australis* Glaessner 1979) were described from the Early Cambrian Emu Bay Shale on the northern shore of Kangaroo Island (Glaessner 1979) in similar lithology. As the specimen is referred to a new genus it provides no basis for correlation at this level; as suprageneric classification of this and similar dissociated carapaces is uncertain no dating is available on a strictly taxonomic basis except that such carapaces are not known from post-Triassic rocks. However, as discussed below, this genus is comparable with several Cambrian genera of bivalve arthropods and is distinct from post-Cambrian forms. Taken together, this biological evidence and the regional geology make a Cambrian age very probable.

PHYLUM: ARTHROPODA
CLASS, ORDER AND FAMILY:
UNCERTAIN
GENUS: *PAPILIOCARIS* nov.

Etymology: From the Latin *papilio* meaning a butterfly and *caris* meaning a shrimp. The name refers to its resemblance to and initial identification as possibly an insect wing. Gender is feminine.

Type species: *Papilocaris arrugia* sp. nov.

Diagnosis: Carapace bivalve with straight hingeline. Valves ovoid, with marked posteroventral expansion; anterior hinge process large and prominent, projecting farthest some distance below hingeline. No marginal spines on

* National Museum of Victoria, 285-321 Russell Street, Melbourne, Vic. 3000

hinge, anterior or ventral margins. Surface with pattern of longitudinal ridges, joined in a meshwork near anterior margin but independent for most of their length and breaking up into short segments in places.

Discussion: The problems of classification of phyllocarid-like carapaces in the absence of thoracic and abdominal details have been extensively considered. (Briggs 1976, 1977; Glaessner 1979 and others). However, isolated carapaces are not uncommon in Palaeozoic sediments and the established generic level taxonomy has proved useful for such fossils (e.g. Robison & Richards 1981). Although a number of phyllocarids are known with longitudinal to oblique ridges (Rolfe 1969) the ornament of this specimen is unknown in any similarly shaped arthropod carapace and together with the nature of the anterodorsal projection forms the basis for the new genus.

Overall shape is most reminiscent of genera such as *Canadaspis* Novozhilov (cf. Briggs 1978, figs 18, 19, 51) whose main distinguishing feature is the posteroventral expansion. The ornament may be functionally similar to the polygonal ornament of *Tuzoia* Walcott (see Robison & Richards 1981, pl. 7, fig. 2) from which it may be derived by streamlining—possibly suggesting a faster moving animal. An alternative argument may be that *Tuzoia* evolved from a smooth form and *Papiliocaris* appears to be an intermediate. A possible functional interpretation of the ridges is that they house a secondary respiratory system as suggested by Jell (1978) for trilobites. The ridges increase the surface area considerably, were ideally situated in the water flow past the body, and their absence posteriorly is understandable also with that interpretation. If this interpretation is correct then no phylogenetic relationship may be inferred from the ornament as such ridges developed in many different trilobite lineages at different times. As these genera, with which some comparison may be made but no certain kinship may be inferred, are all of Early or Middle Cambrian age *Papiliocaris* seems most likely to be of Cambrian age also but this is by no means certain.

***Papiliocaris arrugia* sp. nov.**

Figs 1–2

Etymology: From the Latin *arrugia* meaning a shaft or pit in a mine—referring to its discovery in a borehole.

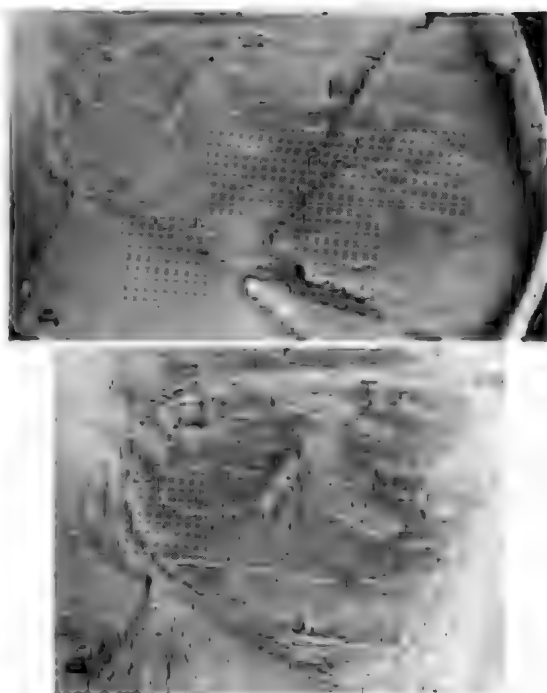


Fig. 1. *Papiliocaris arrugia* sp. nov. GSSA Fossil Collection No. Cr43. A, lateral view of latex cast of external mould of left carapace valve, $\times 3$. B, lateral view of internal mould of anterior half of left carapace valve, $\times 4$.

Material: The holotype carapace registered in the Geological Survey of South Australia Fossil Collection as No. Cr43. It is preserved as internal and external moulds (no shell preserved) with only half the internal mould still present.

Diagnosis: As for genus.

Description Left carapace 37 mm long, 10 mm high at anterior and 22 mm high posteriorly. No rostral plate present. Anterior and ventral profiles broadly convex but original convexity must have been somewhat greater as wrinkles, due to flattening, are visible near hingeline in anterior half and near posteroventral margin. Outline (Fig. 2) drawn from latex cast which shows dorsal part of posterior margin; it is continued posteroventrally in smooth curve. Anteriorly margin turns down from straight hingeline in a little more than 90° angle, curves gently forward for 4 mm, then turns abruptly back parallel to hingeline for a short distance to edge of main body of carapace and from this point again curves forward to most anterior point on margin.



Fig. 2. *Papiliocaris atrugia* sp. nov. Camera lucida sketch and reconstruction of left carapace valve showing pattern of ridges.

Ventrally margin straight to very gently convex and slopes down to produce postero-ventral expansion. Flat narrow border adjacent to margin throughout except anteriorly where considerably wider. Inside the border is the convex body of the carapace. Ornament of prominent longitudinal ridges on body that are linked together anteriorly by two or three vertical ridges running parallel to anterior margin and forming an irregular meshwork en-

closing quadrangular or polygonal shapes. Posteriorly 5 or 6 main ridges wavy, discontinuous in some places and finishing well before posterior margin. On anterodorsal border a few less prominent ridges visible with two running diagonally up and back to hingeline.

Remarks: The sharp break in the anterior margin may well be a fracture of the carapace with the lower part turned down into the matrix; the margin would have been evenly curved if that was the case. However, the margin just below the break appears to be a true edge and the question must remain open. Even if the anterior margin proves not to be distinctive, the carapace ornament is unique so as to warrant erection of the new taxon.

Acknowledgments

I am grateful to Mark Griffiths, the SADME well-site geologist who found the fossil, to Murray Lindsay, David Gravestock and Wolfgang Preiss of SADME for information and comments on a draft of this paper and also to Murray Lindsay for inviting me to describe the fossil.

References

- BRIGGS, D. E. G. (1976) The arthropod *Branchiocaris* n. gen., Middle Cambrian, Burgess Shale, British Columbia. *Bull. geol. Surv. Can.* **264**, 1-29.
- (1977) Bivalved arthropods from the Middle Cambrian Burgess Shale of British Columbia. *Palaeontology* **20**, 595-621.
- (1978) The morphology, mode of life and affinities of *Canadaspis perfecta* (Crustacea: Phyllocarida), Middle Cambrian, Burgess Shale, British Columbia. *Phil. Trans. R. Soc. Lond. ser. B* **281**, 439-87.
- CHAPMAN, F. (1903) New or little known Victorian fossils in the National Museum, Melbourne, Part I, Some Palaeozoic species. *Proc. R. Soc. Vict. (n.s.)* **15**, 104-22.
- DALGARNO, C. R. & JOHNSON, J. E. (1966) PARACHILNA map sheet, Geological Atlas of South Australia, 1:250 000 series. (Geol. Surv. S. Aust., Adelaide.)
- GLAESSNER, M. F. (1979) Lower Cambrian Crustacea and annelid worms from Kangaroo Island, South Australia. *Alcheringa* **3**, 21-31.
- JELL, P. A. (1978) Trilobite respiration and genital caeca. *Ibid.* **2**, 251-60.
- (1980) Two arthropods from the Lancefieldian (La 1) of central Victoria. *Ibid.* **4**, 37-46.
- ROMSON, R. A. & RICHARDS, B. C. (1981) Larger bivalve arthropods from the Middle Cambrian of Utah. *Paleont. Contr. Univ. Kans. Pap.* **106**, 1-19.
- ROLFF, W. D. I. (1966) Phyllocarid crustacean fauna of European aspect from the Devonian of Western Australia. *Nature, Lond.* **209**, 192.
- (1969) Phyllocarida. In *Treatise on Invertebrate Palaeontology Part B Arthropoda* **4**, R. C. Moore, ed., Geol. Soc. Amer. & Univ. Kansas Press, R296-R331.

LATE EOCENE TO LATE OLIGOCENE AGE OF THE KINGSCOTE LIMESTONE, KANGAROO ISLAND, S.A.

BY J. MURRAY LINDSAY

Summary

Tertiary fossiliferous limestones with an apparent exposed thickness of only about 10 m crop out along the coast for about 2 km southwestwards from Kingscote jetty, for the most part dipping gently southeast (i.e. seawards). Elsewhere in this volume these limestones are described and named the Kingscote Limestone. It has been long assumed or implied that these limestones are all of much the same age, whether Miocene, or Eocene, the latter age having been adopted invariably during the past 30 years. However the Kingscote Limestone comprises three units, and foraminiferal studies by the writer have dated these Late (but not latest) Eocene, latest Eocene-Middle Oligocene, and early Late Oligocene. The purpose of this supplementary note is to discuss further some aspects of the dating of foraminifera.

BRIEF COMMUNICATION

LATE EOCENE TO LATE OLIGOCENE AGE OF THE KINGSCOTE LIMESTONE, KANGAROO ISLAND, S.A.

Tertiary fossiliferous limestones with an apparent exposed thickness of only about 10 m crop out along the coast for about 2 km southwestwards from Kingscote jetty, for the most part dipping gently southeast (i.e. seawards). Elsewhere in this volume¹ these limestones are described and named the Kingscote Limestone. It has been long assumed or implied that these limestones are all of much the same age, whether Miocene^{2,3} or Eocene⁴⁻¹², the latter age having been adopted invariably during the past 30 years. However the Kingscote Limestone comprises three units, and foraminiferal studies by the writer have dated these Late (but not latest) Eocene, latest Eocene-Middle Oligocene, and early Late Oligocene¹. The purpose of this supplementary note is to discuss further some aspects of the dating by foraminifera.

Two disconformities within the limestone sequence were recognised during field work by B. J. Cooper in 1976 and B. J. Cooper and A. R. Milnes in (1981). Samples collected in 1976¹³ from strata below the lower disconformity, near Kingscote jetty (Kingscote 1:100 000 sheet, map ref. 390 509) have yielded as expected an Eocene assemblage of foraminifera¹⁴⁻¹⁷, including occasional examples of the planktonic forms *Globigerinatheka index* (Finlay) and *Turborotalia optima nana* (Bolli), together with the benthonic species *Asterigerina adelaidensis* (Howchin), *Crespinina kingscotentis* Wade, *Halkyardia bortrami* Parr¹⁴, *Linderina glaessneri* Quilty¹⁴, *Massilina chapmani* Glaessner & Wade, and *Quastbolivina taylori* Quilty¹⁴. The same unit sampled recently by J. M. Lindsay and B. J. Cooper 1.5 km further to the southwest (Kingscote 1:100 000 sheet, map ref. 377 501; sample F10/82) contains similar benthonics and the additional planktonics *Tenuitella gemma* (Jenkins) and *T. insolita* (Jenkins). The presence of *Turborotalia optima nana* apparently low in this unit suggests an age probably no older than earliest Late Eocene^{18, 19}. The first appearance of *Tenuitella gemma* occurs near the top of Zone P.15, within the Late Eocene^{19, 20}, and this species is also found in the Maclay Bay stratotypes as low as middle Tortachilla Limestone¹⁷. *Globigerinatheka index* and *Tenuitella insolita* are no younger than Late Eocene^{19, 20, 21}. Of the benthonic species listed, *Asterigerina adelaidensis* has the most restricted upward range since in the eastern St Vincent Basin it is not known from above Blanche Point Formation (Late, but not latest Eocene) whereas the others range up further into latest Eocene basal Port Willunga Formation^{17, 19, 20}. *Pseudopolymorphina* sp. cf. *P. carteri* Quilty¹¹ which in the eastern St Vincent Basin has a range restricted

in Tortachilla Limestone and basal Blanche Point Formation^{17, 19, 21, 22}, has not been found yet in any exposures of Kingscote Limestone but does occur subsurface, in all but one instance at the base of the formation¹.

Thus the foraminiferal evidence supports a correlation between the lowest unit of Kingscote Limestone and Tortachilla Limestone plus at least part of Blanche Point Formation¹².

The middle unit of Kingscote Limestone is less than 1 m thick, is bounded by disconformities, and is only known at present from exposures in the Kingscote cliffs¹. Sample F1/82, from the type section of the formation, 150 m southwest of the Kingscote swimming pool, contains small *Subbotina* sp. from the *S. linaperta* (Finlay)—*S. angiporoides* (Hornibrook) group, together with *Textularia* sp. cf. *T. cuspidis* Finlay, *T.* sp. cf. *T. marsdeni* Finlay, *Massilina torquayensis* (Chapman), *Reussella finlayi* Dorreen, and *Gyroldinoides* sp. cf. *G. allani* (Finlay). Sample F5/82 from 400 m further southwest, near Rolls Point, contains *Subbotina angiporoides*, *Massilina torquayensis*, and *Gyroldinoides* sp. cf. *G. allani*, together with specimens of *Asterigerina* (not *A. adelaidensis*), most of them *A.* sp. cf. *A. waikareku* Finlay, but a few *A.* sp. cf. *A. cyclops* Dorreen. The presence of *S. angiporoides* suggests an age no younger than Zone P. 21, since the species is reported to continue only 'into horizons as young as Zone P. 21 ... in cooler water environments'¹⁵. *Massilina torquayensis* is a characteristically Janukian and Oligocene species in southern Australia, but first appeared in South Australia in the latest Eocene^{17, 20, 23}. Published New Zealand ranges of *Textularia cuspidis* (Borlsonian-Whaingaroan), *T. marsdeni* (?Runangan, Whaingaroan-Waiavan), *Reussella finlayi* (Kaikatan-Dunroonian), *Asterigerina waikareku* (Katatan-Runangan, ?Whaingaroan), and *A. cyclops* (Kaikatan-basal Dunroonian)²³, suggest a Runangan-Whaingaroan age for this part of the microfauna. A recent assessment of N.Z. stages in international terms correlates this interval with Zone P. 16-lower Zone P. 21²⁴. Taken together, the foraminiferal evidence dates the middle unit of Kingscote Limestone within the limits of latest Eocene to lower Zone P. 21 (Middle Oligocene). However in the absence of any species restricted to the Eocene, and because the unit is bounded by disconformities, the age is considered more likely to be Early to Middle Oligocene, correlating with the Ruwangan Member of Port Willunga Formation in the eastern St Vincent Basin^{17, 19-22, 25, 26}, and representing deposition during rising global sea level cycle TO 1 of Vail *et al.*^{24, 27, 28}.

The upper unit of Kingscote Limestone is a few metres thick between the Kingscote swimming pool and Rolls Point, 600 m to the southwest¹. Five samples have yielded useful planktonic microfaunas. All contain *Guembelitra samwelli* Jenkins, and all but the stratigraphically highest sample (2 m above the upper disconformity) contain rare to frequent *Chiloguembelina cubensis* (Palmer), suggesting that this unit straddles the *C. cubensis* last appearance datum which is probably within Zone P. 21 in southern Australia^{17, 20, 30}. *Subbotina angiporoides* occurs frequently in three of the five samples (but not in the uppermost), and as noted earlier indicates an age probably no younger than Zone P. 21¹⁶. *Tenuitella genina*, present in

two samples including the topmost, is reported to range up to Zone P. 21 and possibly into the earlier part of Zone P. 22¹². Taking into account the stratigraphic relationships of this upper unit of Kingscote Limestone an early Late Oligocene age is indicated (probably no younger than Zone P. 21, possibly extending into early Zone P. 22). It is possible that the disconformity separating the middle and upper units is a result of the pronounced drop in global sea level that is postulated to have occurred within Zone P. 21, between global sea level cycles TO 1 and TO 2.^{12, 27, 28}

This paper is published with the permission of the Director-General of Mines and Energy.

¹Milnes, A. R., Ludbrook, N. H., Lindsay, J. M. & Cooper, B. J. (1983). Trans. R. Soc. S. Aust. 107, 1-35.

²Tate, R. (1883). *Ibid.* 6, 116-171.

³Chapman, F. (1915). Appendix II in Wade, Arthur. Bull. geol. Surv. S. Aust., 4, 44-50.

⁴Howchin, W. (1899). Trans. R. Soc. S. Aust. 23, 198-207.

⁵— (1903). *Ibid.* 27, 75-90.

⁶Glaessner, M. F. (1953). *Ibid.* 76, 141-146.

⁷Wade, Mary (1955). Contrib. Cushman Fdn foramin. Res. 6, 45-49.

⁸— & Carter, A. N. (1957). Micropaleontology 3, 155-164.

⁹Glaessner, M. F. & Wade, Mary (1958). In Glaessner, M. F. & Parkin, L. W. (Eds), J. geol. Soc. Aust. 5, 115-126.

¹⁰Ludbrook, N. H. (1963). Trans. R. Soc. S. Aust. 87, 5-15.

¹¹Wade, Mary (1964). Micropaleontology 10, 273-290.

¹²Daily, B., Milnes, A. R., Twidale, C. R. & Bourne, J. A. (1979). In Tyler, M. J., Twidale, C. R. & Ling, J. K. (Eds), "Natural History of Kangaroo Island" (Roy. Soc. S. Aust.: Adelaide), pp. 1-38.

¹³SADME Biostratigraphy Section samples F13-15/76.

¹⁴Quilty, P. G. (1981). J. R. Soc. W. Aust. 64, 79-100.

¹⁵Blow, W. H. (1979). "The Cainozoic Globigerinida", 3 vols (E. J. Brill: Leiden).

¹⁶McGowran, B. (1978). In Bull. Bur. Miner. Resour. Geol. Geophys. Aust. 192, 83-95.

¹⁷Lindsay, J. M. (1981). Tertiary stratigraphy and foraminifera of the Adelaide City area, St. Vincent Basin, South Australia, M.Sc. Thesis, University of Adelaide. (unpublished).

¹⁸Jenkins, D. G. (1971). Palcont. Bull., Wellington 42.

¹⁹Lindsay, J. M. (1967). Trans. R. Soc. S. Aust. 91, 93-110.

²⁰— (1970). Q. geol. Notes, geol. Surv. S. Aust. 36, 4-10.

²¹— (1969). Bull. geol. Surv. S. Aust. 42.

²²Cooper, B. J. (1979). Rep. Invest., geol. Surv. S. Aust. 50.

²³Hornibrook, N. de B. (1961). Paleont. Bull., Wellington 34 (1).

²⁴Loutit, T. S. & Kennett, J. P. (1981). Bull. Am. Ass. Petrol. Geol. 65, 1586-1601.

²⁵Cooper, B. J. (1977). Q. geol. Notes, geol. Surv. S. Aust. 64, 2-5.

²⁶Lindsay, J. M. In Daily, B., Firman, I. B., Forbes, B. G. & Lindsay, J. M. (1976). In Twidale, C. R., Tyler, M. J. & Webb, B. P. (Eds), "Natural History of the Adelaide Region" (Roy. Soc. S. Aust.: Adelaide) pp. 5-42.

²⁷Vail, P. R. & Mitchum, R. M. (1979). In Watkins, J. S., Montadert, L. & Dickerson, P. W. (Eds), Mem. Am. Assoc. Pet. Geol. 29, 469-472.

²⁸Vail, P. R. & Hardenbol, J. (1979). Oceanus 22, 71-79.

²⁹McGowran, B., Lindsay, J. M. & Harris, W. K. (1971). In Wopfner, H. & Douglas, J. G. (Eds), Spec. Bull. geol. Surv. S. Aust., Vict., pp. 273-281, encl. 14-1.

³⁰McGowran, B. (1979). Marine Micropaleontology 4, 235-264.

J. MURRAY LINDSAY, Dept of Mines & Energy, Box 151, Eastwood, S. Aust. 5063.

NEOBACTRACHUS SUTOR MAIN: A FROG NEW TO THE FAUNA OF SOUTH AUSTRALIA

BY MICHAEL J. TYLER

Summary

Siince 1966 the number of species of frogs known to occur in South Australia has risen from 16 to 23. Three of these additional species have been discovered in the high rainfall area of the lower southeast of the State, in an area comprising only 1% of the State's surface. The other four were found at isolated localities in the vast and extremely arid north of the State.

BRIEF COMMUNICATION

NEOBATRACHUS SUTOR MAIN: A FROG NEW TO THE FAUNA OF SOUTH AUSTRALIA

Since 1966 the number of species of frogs known to occur in South Australia has risen from 16 to 23¹⁻⁶. Three of these additional species have been discovered in the high rainfall area of the lower southeast of the State, in an area comprising only 1% of the State's surface. The other four were found at isolated localities in the vast and extremely arid north of the State.

The collection of frogs in northern South Australia results commonly from fortuitous events. For example the discovery in 1970 of *Pseudophryne occidentalis* Parker resulted from frogs falling into cardboard containers sunk into the ground by E. Mathews to trap dung beetles³. The presence of *Litoria latopalmata* in South Australia is based on a single specimen taken by M. Davies and M. J. Tyler, amongst a very large series of *Limnodynastes tasmaniensis* Günther emerging from cracks in the ground at the edge of Gidgealpa Waterhole⁴.

Because of the long periods between falls of rain in the north of the State, fossorial species of frogs are most suited to survive there. By far the most commonly encountered fossorial frogs are species of *Neobatrachus* Peters, and all specimens collected in northern S.A. and the Northern Territory hitherto have been reported as *N. centralis* Parker.

Following the description of *N. aquilonius* Tyler, Davies & Martin from the Kimberley Division of W.A.⁷, I re-examined the very large collection of *Neobatrachus* in the South Australian Museum (SAM) and located a series of *Neobatrachus sutor* Main from the extreme northwest of the State. The identification of this series represents evidence of a species formerly not known to occur in South Australia, so increasing the frog fauna of the State to 24 species.

On 15.ii.66 the late Peter Aitken collected 49 specimens of *Neobatrachus* at Mt Lindsay in the Birksgate Range, S.A., located north of the Great Victoria Desert within the Northwest Aboriginal Reserve at 27°02'S, 129°53'E. The specimens were collected following approximately 250 mm of rain. Originally all of the specimens were identified by me as *N. centralis*, and subsequently two were exchanged with other museums. Of the remainder seven are still most appropriately referred to that species, but 39 are *N. sutor* (SAM R7481-91, 7496, 7498-7500, 7502-06, 7508-09, 7511, 7513-14, 7516, 7519-25, 7527-29, 23435). The series of *N. sutor* includes 24 adult males 33.8-42.5 mm in snout to vent length, and 15 adult females (several of which are gravid) ranging 37.6-45.1 mm. In life the species is bronze with numerous small black markings, each of which is clearly demarcated (Fig. 1). It is thus distinguish-



Fig. 1. *Neobatrachus sutor* adult. (Photo: M. Davies.)

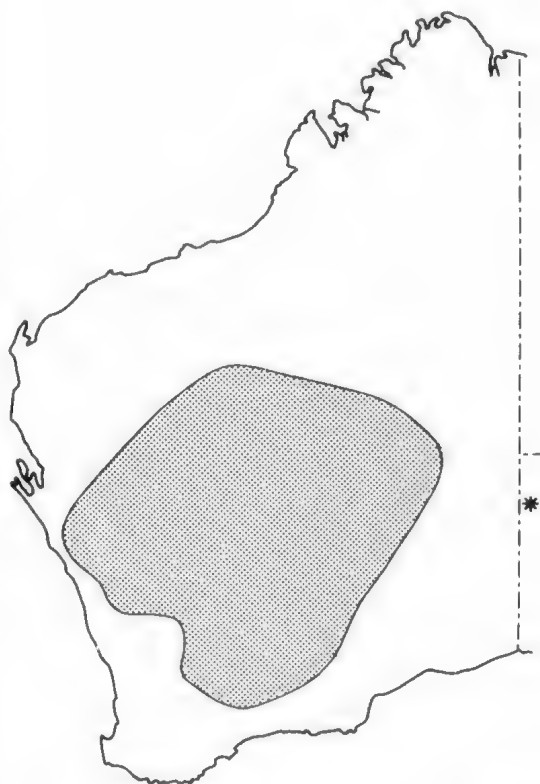


Fig. 2. Distribution of *Neobatrachus sutor* (hatched area). The site of Mt Lindsay is indicated by a star.

able from Eyrean congeners in its small size and superficial appearance, whilst the tapping nature of the male mating call (leading to its colloquial name of the Shoemaker Frog⁸) is equally distinctive from the trills produced by other species.

Neobatrachus sutor occupies the southwest of Western Australia and Mt Lindsay is only 340 km ESE of its currently known western limit in the

Warburton Range (Fig. 2). Its presence in S.A. is therefore of minimal biogeographical significance, but tends to emphasise the fact that the species included in the S.A. frog fauna in part reflects the existence of refugia for more widespread species of western, northern and eastern origin, rather than the State constituting a major site of evolution.

I am indebted to Ruth Hughes for Figure 2.

¹Tyler, M. J. (1966). Frogs of South Australia. South Australian Museum: Adelaide.

²Woodruff, D. S. & Tyler, M. J. (1968). Rec. S. Aust. Mus., 15, 705-709.

³Tyler, M. J. (1971). Trans. R. Soc. S. Aust. 95, 215-217.

⁴Tyler, M. J. (1977). Frogs of South Australia. (Second Edition.) South Australian Museum: Adelaide.

⁵Brooks, J. A. (1980). S. Aust. Nat., 54, 45-46.

⁶Brook, A. J. (1981). Atlas of Frogs of South Australia. Department of Zoology, University of Melbourne Publ. (4), Melbourne. (Mimeo.)

⁷Tyler, M. J., Davies, M. & Martin, A. A. (1981). Rec. W. Aust. Mus. 9, 147-172.

⁸Main, A. R. (1965). Frogs of southern Western Australia. Handbook (8), W.A. Naturalists Club, Perth.

MICHAEL J. TYLER, Department of Zoology, University of Adelaide, Box 498, G.P.O., Adelaide, S. Aust. 5001.

BRIEF COMMUNICATION

REPLACEMENT NAME FOR *LITORIA GLANDULOSA* TYLER & ANSTIS, 1975 (ANURA: HYLIDAE)

Litoria glandulosa Tyler & Anstis (1975)¹ was erected for a hylid frog of northeastern New South Wales and southeast Queensland, formerly confused with *Litoria citropa* (Tschudi). The new species was distinguished from *L. citropa* principally by its smaller adult size and unique tadpole which has an unpigmented and reduced horny beak, and lacks the customary labial tooth rows.

We note that *glandulosa* Tyler & Anstis is a primary homonym, being preoccupied in *Litoria* by *L. glandulosa* Bell (1842)². Bell erected the name for a species taken at Concepcion, Chile by

Charles Darwin. The type specimen of *L. glandulosa* Bell is in poor condition, Gunther (1858, p. 97)³ remarking, "The specimen apparently was in a state of decay before it was put in spirits". Its specific identity remains uncertain, but it has been referred tentatively to the synonymy of *Eupsophus taeniatus* (Girard)⁴.

In accordance with the provisions of the International Code of Zoological Nomenclature, the Australian species requires a replacement name. Accordingly we propose *Litoria subglandulosa* for it.

¹Tyler, M. J. & Anstis, M. (1975). Rec. S. Aust. Mus. 17(5), 41-50.

²Bell, T. (1842). In Darwin, C. "The Zoology of H.M.S. Beagle—1832-36", pt 5, Reptiles, 51 pp.

³Gunther, A. (1858). Catalogue of the Batrachia Salientia in the collection of the British Museum. British Museum, London.

⁴Cei, J. M. (1962). Invest. Zool. Chilenas 7, 7-42.

MICHAEL J. TYLER, Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001, and MARION ANSTIS

COMMENT: LATE PRECAMBRIAN-CAMBRIAN STRATIGRAPHIC NOMENCLATURE IN THE ADELAIDE GEOSYNCLINE

BY J. B. JAGO AND D. B. HILYARD

Summary

Preiss recently proposed that the Late Precambrian and Cambrian rocks of the Adelaide Geosyncline should be placed into three newly erected supergroups, with Warrina Supergroup embracing the Callanna and Burra Groups, Heysen Supergroup to include the Umberatana and Wilpena Groups and Moralana Supergroup to include all the Cambrian rocks. Hence he has added three more names to a sequence which is already overloaded with stratigraphic nomenclature. As stated by Preiss, stratigraphic classification in a depositional basin of the size and duration of the Adelaide Geosyncline is bound to be complicated. However, it is for this very reason that authors should be very careful before adding yet further stratigraphic names. Additional classification implies that the present one is inadequate in terms of the presently understood geology of the Adelaide Geosyncline. However, Preiss makes no attempt either to explain where the present classification is inadequate, or to explain in any detail the need for a supergroup classification. Indeed it would seem to us that a controversial suggestion such as that proposed by Preiss should have been contained in a detailed properly documented paper rather than buried in a "brief communication".

BRIEF COMMUNICATION

COMMENT: LATE PRECAMBRIAN-CAMBRIAN STRATIGRAPHIC NOMENCLATURE IN THE ADELAIDE GEOSYNCLINE

Preiss¹ recently proposed that the Late Precambrian and Cambrian rocks of the Adelaide Geosyncline should be placed into three newly erected supergroups, with **Warrina Supergroup** embracing the Callanna and Burra Groups, **Heysen Supergroup** to include the Umberatana and Wilpena Groups and **Moralana Supergroup** to include all the Cambrian rocks. Hence he has added three more names to a sequence which is already overloaded with stratigraphic nomenclature. As stated by Preiss, stratigraphic classification in a depositional basin of the size and duration of the Adelaide Geosyncline is bound to be complicated. However, it is for this very reason that authors should be very careful before adding yet further stratigraphic names. Additional classification implies that the present one is inadequate in terms of the presently understood geology of the Adelaide Geosyncline. However, Preiss makes no attempt either to explain where the present classification is inadequate, or to explain in any detail the need for a supergroup classification. Indeed it would seem to us that a controversial suggestion such as that proposed by Preiss should have been contained in a detailed properly documented paper rather than buried in a "brief communication".

Preiss¹ notes that the only supergroup nomenclature previously applied to rocks of the Adelaide Geosyncline was the term Adelaide Supergroup², the type area of which is in the Adelaide region. This term includes the presently recognized Burra and Umberatana Groups and part of the Wilpena Group, and as noted by Preiss is not particularly satisfactory when applied to the whole of the Adelaide Geosyncline. Preiss then goes on to state that there is still a need for a higher-rank lithostratigraphic terminology for the Adelaide Geosyncline that is independent of the chronostratigraphic scheme, although what this "need" is he does not state. However Preiss does state that because in his view the sediments of the Adelaide Geosyncline fall into three major sequences, each with its own lithologic, tectonic and palaeogeographic features, and that each is separated from the preceding sequence by a regional unconformity, then a supergroup classification is justified. This seems to us to be simply erecting new stratigraphic names for the sake of it. In any case there are more serious problems as outlined below.

The proposed Warrina Supergroup embraces the Callanna and Burra Groups. However, as Preiss admits some workers^{3,4,5,6} have suggested that there was a major tectonic event between the

completion of the deposition of the Callanna Group and the commencement of deposition of the Burra Group. Indeed, Preiss *et al.* (p. 333)⁷ clearly indicate a considerable break between the base of the Burra Group and the top of the Callanna Group. Despite this Preiss¹ finds the evidence for a post-Callanna-pre-Burra tectonic event "inconclusive" and advances some evidence to support his position. However, it would seem that in the present state of uncertainty about the regional relationship between the Callanna and Burra Groups it would be better to maintain the status quo rather than lump them within a single supergroup.

The proposed Heysen Supergroup combines the Umberatana and Wilpena Groups. If a supergroup nomenclature is to be established then this is the least objectionable of the new names. However, the present arrangement seems perfectly satisfactory with the Umberatana Group encompassing the Late Precambrian glacial and interglacial sequences whereas the Wilpena Group comprises the Late Precambrian post-glacial sequences. In fact to combine them into a single supergroup may obscure this essential difference between the two groups.

The proposed Moralana Supergroup is the most unsatisfactory of the new names. Preiss proposes that it should "include all Cambrian rocks in the Adelaide Geosyncline". This is incorrectly introducing a time element into a lithostratigraphic classification. In any case we would suggest that the grouping of such quite different rock groups as the Normansville and Kanmantoo Groups into a single supergroup is incorrect. The rocks within a supergroup should have significant unifying features⁸ and apart from a Cambrian

¹Preiss, W. V. (1982). Trans. R. Soc. S. Aust. 106, 81-83.

²Daily, B. (1963). Rec. S. Aust. Mus. 14, 579-601.

³Kitch, R. B. (1975). Proterozoic Geology, Geol. Soc. Aust. 1st. Aust. Geol. Conv. Abstr., 6-7.

⁴Murrell, B. (1975). *Ibid.*, 8-9.

⁵Rowlands, N. J., Blight, P. G., Jarvis, D. M. & von der Borch, C. C. (1980). J. geol. Soc. Aust. 27, 55-68.

⁶Murrell, B. (1977). Ph.D. thesis, Univ. Adelaide (unpublished).

⁷Preiss, W. V., Rutland, R. W. R. & Murrell, B. (1981). In Hunter, D. (Ed.) "Precambrian of the Southern Hemisphere", 327-354. (Elsevier: Amsterdam).

⁸Jedberg, H. D. (Ed.) (1976). "International Stratigraphic Guide". (Wiley-Interscience: New York).

age it is difficult to see what the rocks of the Normanville Group (essentially shallow water carbonates overlain by low energy shales and carbonates) have in common with the very thick, rapidly deposited, sandstones and siltstones, including probable turbidites, of the Kanmantoo Group. Indeed the contact between the Normanville and the Kanmantoo Group at Carrickalinga Head is very sharp and reflects the Early Cambrian Kangarooian Movements of Yorke Peninsula and Investigator Strait⁹ which resulted in a considerable local unconformity within the Cambrian succession on Yorke Peninsula. It would seem to us that the combining of all the Adelaide Geosyncline Cambrian rocks into a single supergroup is

going to obscure, or at the very least oversimplify, the quite complex relationships indicated by Daily¹⁰ between the different Cambrian rocks of the Adelaide Geosyncline.

Hence we would suggest that the nomenclature proposed by Preiss is unnecessary and tends to gloss over significant sedimentary and tectonic differences within the sequences drawn together in his three new supergroups.

⁹Daily, B. & Milnes, A. R. (1971). Trans. R. Soc. S. Aust. 95, 199-214.

¹⁰Daily, B. (1976). 25th Int. Geol. Congr., Sydney. Excursion Guide 33A, 15-19.

REPLY: LATE PRECAMBRIAN-CAMBRIAN STRATIGRAPHIC NOMENCLATURE IN THE ADELAIDE GEOSYNCLINE

BY WOLFGANG V. PREISS

Summary

The objections of Jago & Hilyard to my proposed supergroup classification appear not to derive support from currently recognised stratigraphic codes. The International Stratigraphic Guide (p. 34) states: "The term supergroup may be used for several associated groups, or for associated formations and groups with significant features in common". The desirability of such a classification became evident as a result of a compilation of data by the Geographical Survey for a regional synthesis on the Adelaide Geosyncline. The existing nomenclature of the Adelaide Geosyncline may appear "overloaded", but this complication merely reflects the complexity of vertical and horizontal facies variations in such a large and long-lived basin. I know of no stratigraphic guide that stipulates a limit to the number of lithostratigraphic names permitted for a basin.

BRIEF COMMUNICATION

REPLY: LATE PRECAMBRIAN-CAMBRIAN STRATIGRAPHIC NOMENCLATURE IN THE ADELAIDE GEOSYNCLINE

The objections of Jago & Hilyard to my proposed supergroup classification appear not to derive support from currently recognised stratigraphic codes. The International Stratigraphic Guide¹ (p. 34) states: "The term *supergroup* may be used for several associated groups, or for associated formations and groups with significant features in common". The desirability of such a classification became evident as a result of a compilation of data by the Geological Survey for a regional synthesis on the Adelaide Geosyncline. The existing stratigraphic nomenclature of the Adelaide Geosyncline may appear "overloaded", but this complication merely reflects the complexity of vertical and horizontal facies variations in such a large and long-lived basin. I know of no stratigraphic guide that stipulates a limit to the number of lithostratigraphic names permitted for a basin.

The addition of the new names does not imply that the existing nomenclature is inadequate; it only assembles existing groups and formations into larger packages. Jago & Hilyard dispute the need for such groupings, yet the need has clearly been felt by the many authors who have either adopted Daily's² term Adelaide Supergroup, or have used *chronostratigraphic* terms such as "upper Adelaidean" and "lower Adelaidean" instead, even where a lithostratigraphic sense was intended. If Jago & Hilyard do not find my new terms useful, then they are at liberty to ignore them.

The more specific objections also require comment. The most serious pertains to the relationship between the Collanna and Burra Groups, which is admittedly poorly understood. Nevertheless, these groups have so many clastic and carbonate facies in common that the differences between them are more of degree than kind. Sedimentation in both was substantially limited to a trough that was largely co-extensive with the present Flinders and Mount Lofty Ranges³. Unconformity between these groups, where proven, was due to differential uplift in marginal areas, which can be explained by continued rifting and need not involve a regional deformational event, nor indeed any interruption of deposition at this time in the depocentres. But even if *regional* disconformity is demonstrated by future work, the close facies affinity of the two groups will still permit placing them into a single supergroup.

There can surely be no objection to grouping

the Umberatana and Wilpena Groups since the contact between them is a perfectly conformable transition. Although the Umberatana Group includes both major glacial sequences, it also contains evidence of a major interglacial transgressive-regressive cycle³ which is entirely analogous to the post-glacial (transgressive-regressive) cycle of the lower Wilpena Group⁴.

There has previously not been a term analogous to Daily's "Adelaide Supergroup" to cover the Cambrian rocks of the Adelaide Geosyncline. However, the fact that all the units of the Morulana Supergroup are of Cambrian age is in a sense irrelevant. The same arguments would apply had deposition ranged continuously into the Ordovician or younger. I have not, therefore, introduced a time element into lithostratigraphic classification, as Jago & Hilyard claim. I concede that there may be some argument against placing the shelf carbonates of the Hawker and Normanyville Groups with the deeper water clastics of the Kanmantoo Group into the Morulana Supergroup. But even if the Kanmantoo Group were entirely of turbidite origin, it was deposited without substantial interruption, as a trough developed by differential subsidence upon the former carbonate shelf. The combination of the Hawker, Normanyville, Kanmantoo and Lake Frome Groups into a single supergroup does not deny the differences of depositional style between these groups, but implies only that they are more closely associated with each other than they are with the Heysen and Warrina Supergroups.

The classification of rock sequences into supergroups is thus largely a matter of judgement as to the degree of association between those sequences, and differences of opinion may be expected.

This paper is published with the permission of the Director-General of Mines & Energy.

¹Hedberg, H. D. (1976). "International Stratigraphic Guide". (J. Wiley and Sons: N.Y.).

²Daily, B. D. (1963). Rec. S. Aust. Mus. 14, 579-601.

³Rutland, R. W. R., Parker, A. J., Pitt, G. M., Preiss, W. V. & Murrell, B. (1981) In Hunter, D. R. "Precambrian of the Southern Hemisphere" (Elsevier: Amsterdam).

⁴Plummer, P. S. (1978). Trans. R. Soc. S. Aust. 102, 25-38.

ADDITIONS TO THE MARINE FISH FAUNA OF SOUTH AUSTRALIA

BY C. J. M. GLOVER AND K. L. BRANDEN

Summary

Four fishes are new records for South Australian coastal waters. Three species (*Gymnothorax prasinus*, *Saurida undosquamis*, *Tetrapterus angustirostris*) are also first records for their respective families (Muraenidae, Synodontidae, Istiophoridae). All species have been recorded elsewhere off the Australian coast; two are endemic to Australian waters (*G. prasinus*, *Neatypus obliquus*), one is recorded in northern and southern Indo-Pacific waters (*S. undosquamis*) and another in waters around the world (*T. angustirostris*).

BRIEF COMMUNICATION

ADDITIONS TO THE MARINE FISH FAUNA OF SOUTH AUSTRALIA

Four fishes are new records for South Australian coastal waters. Three species (*Gymnothorax prasinus*, *Saurida undosquamis*, *Tetrapterus angustirostris*) are also first records for their respective families (Muraenidae, Synodontidae, Istiophoridae). All species have been recorded elsewhere off the Australian coast: two are endemic to Australian waters (*G. prasinus*, *Neatypus obliquus*), one is recorded in northern and southern Indo-Pacific waters (*S. undosquamis*) and another in waters around the world (*T. angustirostris*).

All represent substantial extensions of the species ranges in the Australian region. For *N. obliquus* supplementary sightings suggest that its occurrence reflects a sustained extension of distribution. Lack of further sightings for the other species imply strayed individuals from outside the South Australian region. It is significant that all species appear to be inhabitants of waters warmer than those which predominate off most of the South Australian coast.

The specimens are deposited in the South Australian Museum (SAM).

Family Muraenidae. *Gymnothorax prasinus*

Muraena prasina Richardson, 1848, Zool. Voy. Erebus & Terror, 2, Fish, 93.

A single specimen (Fig. 1) was captured in a craypot at Cape Radstock, far west S. Aust. (approx. 33°12'S, 134°20'E), during the period December 1979–February 1980, by Mr R. A. Grocke.

G. prasinus has been recorded previously in waters of western and south-western Western Australia, Victoria, New South Wales, Queensland and (?) Northern Territory¹⁻⁴, unpubl. recs.



Fig. 1. *Gymnothorax prasinus*. SAM F4642. TL (total length) 933 mm (Scale in cms).

Family Synodontidae. *Saurida undosquamis*

Saurus undosquamis Richardson, 1848, Zool. Voy. Erebus & Terror, 2, Fish, 138–139, pl. 51 figs 1–6.

A single specimen (Fig. 2) was captured in a prawn trawl net about 12 km south of Venus Bay, far west S. Aust. (approx. 33°21'S, 134°41'E), early in September 1972, by Mr J. Zemke.

S. undosquamis has been recorded in waters of north-western and western Western Australia,



Fig. 2. *Saurida undosquamis*. SAM F3667. TL 340 mm

New South Wales, Queensland and the Northern Territory^{2-3,6}.

Family Scorpididae. *Neatypus obliquus*

Neatypus obliquus Waite, 1905, Rec. Aust. Mus. 6(2), 65-66, pl. 10.

Two specimens (Fig. 3) were captured by S. Aust. Dept. of Fisheries divers at 21.3 m depth off Smooth Island, near St Francis Island, far west S. Aust. (approx. 32°29'S, 133°18'E), in March 1982. Dept. of Fisheries divers also report having sighted the species off Pearson Islands (approx. 33°57'S, 134°16'E), Cape Adieu (approx. 32°00'S, 132°09'E), and at 15 m depth at 'The Hot Spot', between Flinders and Ward Islands (approx. 33°41'S, 134°23'E), far west S. Aust., in March 1982.

N. obliquus has been recorded only in waters of western and south-western Western Australia,

between the Houtman Abrolhos islands (off Geraldton) and the Recherche Archipelago (near the western extremity of the Great Australian Bight)^{1,3,5-6}.

Family Istiophoridae. *Tetrapterus angustirostris*

Tetrapterus angustirostris Tanaka, 1914-15, Figs and Descrs. Fishes of Japan, 1914, 18, pl. 88 fig. 285; *Ibid.* 1915, 19, 324-326.

A single specimen (Fig. 4) was captured by hand in very shallow water at Hallett Cove, south of Adelaide, S. Aust. (35°05'S, 138°30'E), on 23 May 1979, by Messrs G. Thomas, B. Rakocvic, V. Decasta and J. Centrone. The head bones were later retained as SAM F4683.

T. angustirostris has been recorded in Australia only at North Cottesloe and Safety Bay, near Perth, Western Australia (approx. 31°39'S, 115°45'E & 32°18'S, 115°43'E respectively), and at Port Stephens, northern New South Wales (32°42'S, 152°06'E)^{7,8}, unpubl. recs.

The latitude of this new record (35°05'S) corresponds to the southernmost world distributional limit reported for *T. angustirostris*⁹. This is also one of the very rare records of the species from shallow coastal waters: Merrett¹⁰ stated that no specimen had been caught from less than 500 fathoms (911.4 m), although McKay⁷ pointed out that the Cottesloe specimen appeared to be the first taken in shallow coastal waters anywhere in the world.

We thank those persons mentioned for collecting and donating the specimens to the S. Aust. Museum; Mr K. Jury (*Advertiser*) and Mr E. Palmer (S. Aust. Game Fishing Association) for assistance in connection with the *T. angustirostris* record.

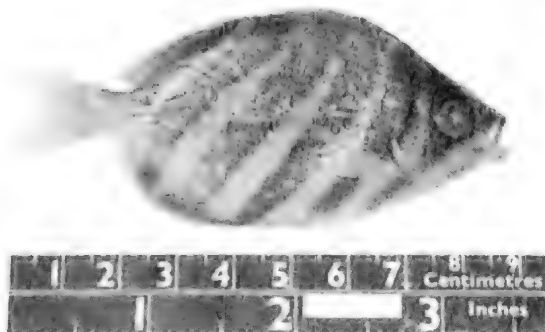


Fig. 3. *Neatypus obliquus*. SAM F4567. TL 91 mm (largest specimen).



Fig. 4. *Tetrapterus angustirostris*. First specimen caught in S. Aust. TL approx. 1524 mm.

- ¹**McCulloch, A. R.** (1929-30). *Mem. Aust. Mus.* 5(1-4), i-x and 1-534.
- ²**Munro, I. S. R.** (1957). *Fish. Newsl.* 16(6), 15-18.
- ³**Whitley, G. P.** (1948) *Fisheries Bulletin No. 2*, 1-35. Western Australia Fisheries Department, Perth.
- ⁴**Marshall, T. C.** (1964). *Fishes of the Great Barrier Reef and coastal waters of Queensland*. Angus & Robertson, Sydney.
- ⁵**Steene, R. C.** (1978). *Butterfly and Angelfishes of the World*. Vol. 1 Australia. A. H. & A. W. Reed, Sydney.
- ⁶**Hutchins, B.** (1979). *The Fishes of Rottnest Island*. Creative Research, Perth.
- ⁷**McKay, R. J.** (1966). *W.A. Nat.* 10(3), 75-76.
- ⁸**Goadby, I. P.** (1972). *Big Fish and Blue Water*. Gamefishing in the Pacific (second revised edition). Angus & Robertson, Sydney.
- ⁹**Nakamura, I.** (1974). NOAA Tech. Rpt. NMFS SSRF-675, 45-53.
- ¹⁰**Merrett, N. R.** (1971). *J. Zool., Lond.* 163, 351-395.

C. J. M. GLOVER, South Australian Museum, North Terrace, Adelaide, S. Aust. 5000 and K. L. BRANDEN, Department of Fisheries, 25 Grenfell Street, Adelaide.

ESTIMATION OF SHEEP STOCKING INTENSITY AT ANY LOCATION IN ARID ZONE PADDOCKS

BY R.T. LANGE

Summary

In the South Australian arid zone, over 60 species of endangered native flora are exposed to sheep grazing within the wire-fenced large enclosures called paddocks, which the pastoral industry has superimposed on approximately 220 000 km² of landscape. A problem for botanists who wish to evaluate the consequences to these endangered species, is how to estimate the sheep stocking intensities in each of those parts of the paddocks where endangered species occur (Fig. 1). This note explains an approximate solution.

BRIEF COMMUNICATION

ESTIMATION OF SHEEP STOCKING INTENSITY AT ANY LOCATION IN ARID ZONE PADDOCKS

In the South Australian arid zone, over 60 species of endangered native flora¹ are exposed to sheep grazing within the wire-fenced large enclosures called paddocks, which the pastoral industry has superimposed on approximately 220 000 km² of landscape. A problem for botanists who wish to evaluate the consequences to these endangered species, is how to estimate the sheep stocking intensities in each of those parts of paddocks where endangered species occur (Fig. 1). This note explains an approximate solution.

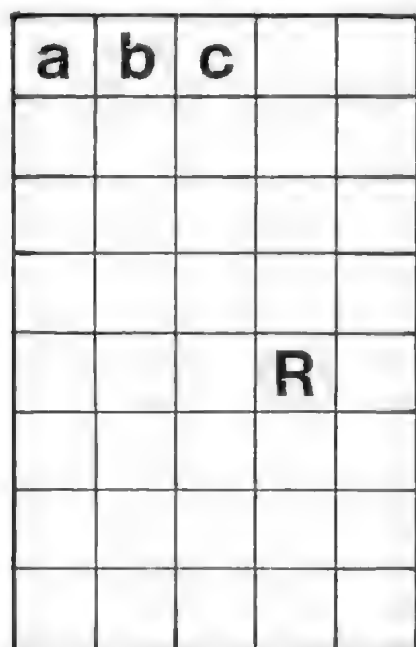


Fig. 1. Hypothetical large sheep paddock in the arid zone with endangered plants at *R* and the paddock considered to consist of *n* equal parts *a*, *b*, *c*

Experiments in that region showed that 15–20 sheep ranging free in experimental paddocks of 2–4 ha exhibited the same behavioural cycle² as did flocks in adjoining large paddocks. The experimental sheep also tended to deposit egesta unequally on the various parts of their paddocks (divided into 14–30 parts) in proportion to the flocktime which they spent on them, provided accumulation periods exceeded 2 days.

In 3 experiments each in different years, regressions between egesta recovered from the parts (*y* Kg oven dry) versus sheeptime spent on the

parts (*x* sheep minutes) were very highly significant. Lines of best fit in the 3 experiments were $y = 0.19 + 0.0005x$, $r^2 = 0.92$, $n = 30$, $p < 0.001$ N.S.

$y = 0.19 + 0.0003x$, $r^2 = 0.96$, $n = 14$, $p < 0.001$ $p < 0.05$.

$y = 0.08 + 0.0006x$, $r^2 = 0.98$, $n = 17$, $p < 0.001$ N.S.

The data-set for the first of these equations is already published³; but that for the second is

<i>y</i>	1.050	1.323	.575	.644	.739	1.191	.622
<i>x</i>	1654	3695	649	843	1284	4132	858
<i>y</i>	.683	.610	2.004	1.126	1.000	1.300	3.826
<i>x</i>	952	1725	6591	2782	1471	4429	12230

and that for the third is

<i>y</i>	.135	.258	.249	.669	.176	.184	.416	.457	.354
<i>x</i>	115	547	192	561	176	158	586	422	370
<i>y</i>	.235	.406	.504	2.935	2.058	9.125	0	0	
<i>x</i>	436	965	980	3105	4.427	15552	0	216	

The marginally-significant intercept in one experiment (as if some egesta for no sheeptime) is considered to be an artifact; the two variables are in general directly proportional. Slope differences reflect differences in pasture condition between years. There is no impediment to the following argument, which requires only proportionality in the given case, regardless of slope.

In any part of adjoining large industrial paddocks, where endangered species occur, stocking intensity in that part (SIP) over a given period would be

area of the part (ha)

paddock flocksize \times fraction of total flocktime spent in the part (*F*)
= SIP (ha sheep⁻¹)

Substituting the relevant fraction of paddock total egesta deposition for *F* allows an approximate solution of the equation. The egesta fraction has to be obtained by sampling since industrial paddocks are too large (2000–20 000 ha) to permit total recoveries.

Applications indicate that at typical paddock stocking rates in the Whyalla region (6–7 ha sheep⁻¹), yearly SIP may vary from 0.5 ha sheep⁻¹ or heavier, through all intermediate levels to 300-sheep⁻¹ or lighter. The sheep grazing stress imposed upon endangered species varies accordingly. Detailed cases and their implications will be described later.

¹Leigh, J., Briggs, J. & Hartley, W. (1981) W. Aust. Nat. Parks and Wildlife Serv. Spec. Pub. 7.

²Moore, P. D. (1976) Nature 262, 6–7.

³Lange, R. T. & Willencks, M. C. (1979) Aust. J. Exp. Agric. An. Husb. 18, 764–767.

SOLUBLE IONS IN RAINWATER COLLECTED NEAR ALICE SPRINGS, N.T., AND THEIR RELATION TO LOCALLY DERIVED ATMOSPHERIC DUST

BY J. T. HUTTON

Summary

During the period October 1957 to January 1962, twenty-two samples of rainwater were collected at Conner's Well, 100 km north of Alice Springs and analysed in Adelaide using established methods.

BRIEF COMMUNICATION

SOLUBLE IONS IN RAINWATER COLLECTED NEAR ALICE SPRINGS, N.T., AND THEIR RELATION TO LOCALLY DERIVED ATMOSPHERIC DUST

During the period October 1957 to January 1962, twenty-two samples of rainwater were collected at Conner's Well, 100 km north of Alice Springs and analysed in Adelaide using established methods¹.

The composition of the soluble material in the rain varied greatly as shown by the detailed results². Table 1 gives data for three typical samples and the weighted average (sum of concentration \times amount of rain / total rain sampled) for all samples.

The average annual rainfall just north of Alice Springs is about 250 mm, the vegetation is sparse and the nearest part of the southern Indian Ocean is 1000 km away. Thus there should be little oceanic salt suspended in the atmosphere and most of the ions are likely to be of local origin. The data in Table 1 confirm this for they show the ratio of the cations, sodium, calcium, magnesium and potassium in the rainwater to those in the Todd River Water is fairly constant and the ratio of calcium and potassium to chloride in the rainwater is at least twenty times the ratios of these ions in seawater.

Three other studies of rain collected in inland areas also show the strong influence of the surrounding environment. For example, it was concluded from the correlation between nitrate and chloride and the presence of burnt pasture debris that the ions in the rain at Katherine, N.T. had come from plant residues and surface soils³. At Merbein in the Mildura district it has been shown⁴

over a period of six summers, 1956 to 1961, the weight of calcium deposited per hectare in summer was inversely related to the rainfall recorded in the district during the two previous springs and winters—

$$\text{calcium (kg/ha/3mth)} = 17.9 - 0.080 (\text{av } 2\text{yr Jne/Nov rain, mm}) \quad r^2 = 0.805$$

In the third case, data show that at Wiluna, in the arid Murchison District of Western Australia, the amount of dissolved salts in the rain is about twenty times that found in the rain at nearby Meekatharra, Mt Newman and Three Rivers and this is due to a large salt lake, Lake Way, being only 10 km south of the town of Wiluna.

Thus inland in semi-arid and arid regions, the material in the rain is related to the surrounding surface—a salt lake near Wiluna, calcareous surface soils surrounding Mildura, the vegetation and soils near Katherine and the soils in the Alice Springs area with soluble salts represented by those dissolved in the Todd River. The soluble material in the rain is derived from the material suspended in the atmosphere through which the rain drops have fallen. Rain, however, falls only occasionally in these semi-arid regions and so the amount of material in it can represent only a small fraction of the amount of material of local origin in the atmosphere throughout a year.

Accessions calculated from the analysis of rainwater are not an absolute accession to an area but a small return of a much larger loss of material suspended in the atmosphere as aerosolic dust.

TABLE 1. Soluble ions in rain and Todd River water, Alice Springs.

Sample	Rainfall, mm	Na	Ca	Mg	K μ -equiv./litre	Cl	HCO ₃	SO ₄
15/5/58	6	56	140	50	25	100	70	80
13/11/58	30	8	20	10	2	4	20	20
5/12/60	15	31	20	20	8	14	50	
Av. of 22	14	28	32	23	9	25	39	<30
Todd River ⁵ 23/10/61		260	450	330	100	140	770	<40
Ratio Todd water Av. rain		9	14	14	11	6	20	-

¹Hutton, J. T. & Leslie, T. J. (1958). *Aust. J. agric. Res.* 9, 492.

²Hutton, J. T. (1962). CSIRO Div. Soils, Adelaide. Div. Rpt 7/62.

³Williams, W. D. & Siebert, B. D. (1963). *Aust. J. Mar. Freshw. Res.* 14, 166.

⁴Wetselaar, R. & Hutton, J. T. (1963). *Aust. J. agric. Res.* 14, 319.

⁵Hutton, J. T. (1980). In Storrier, R. R. & Stannard, M. E. (eds) "Aeolian landscapes in the semi-arid zone of south-eastern Australia." *Aust. Soc. Soil Science, Riverina Branch*. Wagga Wagga.

⁶Hingston, F. J. & Gailitis, V. (1977). CSIRO Div. Land Resources Management, Perth, Tech. Mem. 77/1.

Transactions of the Royal Society of South Australia Incorporated

Contents

Barker, S.	New synonyms and new species of <i>Stigmodera</i> (<i>Castiarina</i>) (Coleoptera: Buprestidae)	139
Plummer, P. S.	Correlation of the uppermost Late Precambrian Succession across the Torrens Hinge Zone in the Port Augusta region of South Australia	171
Slansky, E.	Halloysite in a weathered profile at Port Macquarie, New South Wales	177
Kailola, Patricia J.	<i>Arius graeffei</i> and <i>Arius armiger</i> : valid names for two common species of Australo-Papuan fork-tailed catfishes (Pisces, Ariidae)	187
Banks, C. B., Birkett, J. R., Dunn, R. W. & Martin, A. A.	Development of <i>Litoria infrafrenata</i> (Anura: Hylidae)	197
Shepley, E. Ann & Womersley, H. B. S.	The Dumontiaceae (Cryptonemiales: Rhodophyta) of southern Australia	201
Dulhunty, J. A.	Lunettes of Lake Eyre North, South Australia	219
Skinner, S.	Some freshwater Chlorophyta from the Bool Lagoon system in south-eastern South Australia	223
Harvey, C.	A new species of <i>Nephurus</i> (Reptilia: Gekkonidae) from South Australia	231
Tyler, M. J., Davies, M. & Martin, A. A.	The frog fauna of the Barkly Tableland, Northern Territory	237
Tyler, M. J., Watson, G. F. & Davies, M.	Additions to the frog fauna of the Northern Territory	243
<i>Brief communications:</i>		
Mawson, Patricia M.	On the status of some nematode species from Australian birds	247
Riley, G. G., Milnes, A. R. & Bourman, R. P.	Landscape models for earth science research	249
Wright, M. J.	Red-brown hardpans and associated soils in Australia	252

TRANSACTIONS OF THE

ROYAL SOCIETY

OF SOUTH AUSTRALIA

INCORPORATED

VOL. 107, PART 3

NEW SYNONYMS AND NEW SPECIES OF STIGMODERA (CASTIARINA) (COLEOPTERA: BUPRESTIDAE)

BY S. BARKER

Summary

Nine new synonyms of *Stigmodera* (Castiarina): *danesi* Obenberger 1933 = *castelnaudi* Saunders 1869; *sancta* Carter 1913 = *cupricollis* Saunders 1868; *acuta* Deuquet 1956 = *delicatula* Kerremans 1902; *georgiana* Barker 1979 = *domina* Carter 1931; *canaliculata* Blackburn 1892 = *erythroptera* (Boisduval) 1835; *cognata* Kerremans 1898 = *insularis* Blackburn 1897; *equina* Blackburn 1892 = *simulata* L. & G. 1837; *garrawillae* Carter 1931 = *subgrata* Blackburn 1900; *opacipennis* Obenberger 1922 = *undulata* (Donovan) 1805, are recognised. Ten species (*S. broomensis*, *S. decemguttata*, *S. hostilis*, *S. marginicollis*, *S. sieboldi*, *S. parvula*, *S. timida*, *S. vegeta*, *S. triramosa*, *S. leai*) are resurrected from synonymy. Thirty-one new species of the subgenus *Castiarina* (*alpestris*, *armstrongi*, *boldensis*, *chinnocki*, *cornishi*, *dingoensis*, *eneabba*, *euclae*, *forresti*, *frauciana*, *furtiva*, *goldingi*, *goodingi*, *hanloni*, *hypocrita*, *jeanae*, *kalbarri*, *marginata*, *powelli*, *pseudasilida*, *pseuderythroptera*, *scintillata*, *storeyi*, *subtestacea*, *subvicina*, *supergrata*, *thurmerae*, *tigris*, *turneri*, *variegata*, *yellowdinensis*) are described and illustrated in colour. Male genitalia of all but one are illustrated together with related species. One species given varietal status by Blackburn is elevated to full species status, *Stigmodera* (Castiarina) *deserti* Blackburn 1892, and redescribed.

NEW SYNONYMS AND NEW SPECIES OF *STIGMODERA* (*CASTIARINA*) (COLEOPTERA: BUPRESTIDAE)

by S. BARKER*

Summary

BARKER, S. (1983) New synonyms and new species of *Stigmodera* (*Castiarina*) (Coleoptera: Buprestidae). *Trans. R. Soc. S. Aust.* 107(3), 139-169, 30 November, 1983.

Nine new synonyms of *Stigmodera* (*Castiarina*): *danesi* Obenberger 1933 = *castelnaudi* Saunders 1869; *sacra* Carter 1913 = *cupricollis* Saunders 1868; *acuta* Deuquet 1956 = *delicatula* Kerremans 1902; *georgiana* Barker 1979 = *domina* Carter 1931; *canaliculata* Blackburn 1892 = *erythroptera* (Boisduval) 1835; *cognata* Kerremans 1898 = *insularis* Blackburn 1897; *equina* Blackburn 1892 = *stimulata* L. & G. 1837; *garrawillae* Carter 1931 = *subgrata* Blackburn 1900; *opacipennis* Obenberger 1922 = *undulata* (Donovan) 1805, are recognised. Ten species (*S. broomensis*, *S. decemguttata*, *S. hostilis*, *S. marginicollis*, *S. sieboldi*, *S. parvula*, *S. finida*, *S. vegeta*, *S. triramosa*, *S. leai*) are resurrected from synonymy. Thirty-one new species of the subgenus *Castiarina* (*alpestris*, *armstrongi*, *boldensis*, *chunocki*, *cornishi*, *dungenensis*, *eneabba*, *euclae*, *forresti*, *franciana*, *furtiva*, *goldingi*, *goodingi*, *hanloni*, *hypocrita*, *jeanae*, *kalbarri*, *marginata*, *pavelli*, *pseudasilida*, *pseuderythroptera*, *scintillata*, *storeyi*, *subtestacea*, *subviciua*, *supergrata*, *thurmerae*, *ligris*, *turneri*, *variegata* *yellowdinensis*) are described and illustrated in colour. Male genitalia of all but one are illustrated together with related species. One species given varietal status by Blackburn is elevated to full specific status. *Stigmodera* (*Castiarina*) *deserti* Blackburn 1892, and redescribed.

KEY WORDS: Coleoptera, Buprestidae, *Stigmodera* (*Castiarina*), new species, synonyms.

Introduction

More than 300 species of *Stigmodera* (*Castiarina*) have been described representing about 1/3 of the known Buprestid fauna of Australia. They are a difficult group because many of the early descriptions are inadequate. A number of mimicry complexes occur and members resemble each other so closely that they are frequently confused, and misidentified. A revision of the sub-genus was commenced in 1969 and although much has been accomplished, completion is unlikely before 1986 when it is anticipated the work will be published in the South Australian Handbook series as brief descriptions, illustrations and keys. Interest in the group is growing and increased collecting has produced many new species. In this paper, 31 new species are described and illustrated together with redescription and/or illustrations of 10 species that are poorly known. A number of types have been re-examined and some of the synonyms of earlier workers and some of my own synonyms have been found to be incorrect (Barker, 1979, 1980). These errors are rectified below.

An almost complete collection is available in the South Australian Museum for comparison.

New synonyms of *Stigmodera* (*Castiarina*)

- castelnaudi* Saunders 1869, *Insect. Saund.* 3, p. 9.
- danesi* Obenberger 1933, *Čas. čsl. Spol. entom.* 30, p. 73.
- cupricollis* Saunders 1868, *J. Linn. Soc.* 9, p. 470.
- sacra* Carter 1913, *Proc. Linn. Soc. N.S.W.* 37, p. 501.
- delicatula* Kerremans 1902, *Genera Insect.* 12, p. 209.
- acuta* Deuquet 1956, *Proc. Linn. Soc. N.S.W.* 81, p. 154.
- domina* Carter 1931, *Aust. Zool.* 6, p. 344.
- georgiana* Barker 1979, *Trans. R. Soc. S. Aust.* 103, p. 7.
- erythroptera* (Boisduval) 1835, *Voyage de l'Astrolabe*, p. 88.
- canaliculata* Blackburn 1892, *Trans. R. Soc. S. Aust.* 15, p. 51.
- insularis* Blackburn 1897, *Trans. R. Soc. S. Aust.* 21, p. 30.
- cognata* Kerremans 1898, *Annls. Soc. ent. Belg.* 42, p. 136.
- stimulata* L. & G. 1837, *Mon. Bupr.* 2, p. 26.
- equina* Blackburn 1892, *Trans. R. Soc. S. Aust.* 15, p. 48.
- subgrata* Blackburn 1900, *Trans. R. Soc. S. Aust.* 26, p. 41.
- garrawillae* Carter 1931, *Aust. Zool.* 6, p. 348.
- undulata* (Donovan) 1805, *Epitome Natural History Insects New Holland* pl. 7, fig. 5.
- opacipennis* Obenberger 1922, *Arch. Naturgesch.* 1922, 88, p. 116.

* Department of Zoology, University of Adelaide, Box 498, G.P.O., Adelaide, S. Aust. 5001.

Species resurrected from synonymy

Barker (1979, p. 15) wrongly synonymised *S. broomensis* Carter 1934 with *S. biguttata* Macleay 1863. The two species occur on opposite sides of the continent. *S. broomensis* in north western Australia and *S. biguttata* in Queensland. They have a recognisable difference in their elytral patterns. *S. broomensis* is lightly marked while *S. biguttata* is more heavily marked. Male genitalia (Figs 1A, 1B) differ, the parameres in *S. broomensis* being rounded abruptly to the apex while those of *S. biguttata* are gradually rounded to the apex. I therefore consider *S. broomensis* Carter a valid species.

S. decemguttata Gory 1841 (Fig. 4C) was synonymised with *S. versicolor* L. & G. 1837 (Fig. 4D) by Saunders (1871). He was followed by Kerremans (1902), Carter (1916, 1931) and Barker (1979). Obenberger (1934) resurrected *S. decemguttata* and listed *S. parva* Saunders as a synonym. Carter (1940) said *S. parva* was not a synonym of *S. decemguttata* but did not discuss their status, having previously listed both as synonyms of *S. versicolor* (Carter, 1931). I have examined coloured photographs of the original plates in the Laporte & Gory monograph and have identified specimens of the species depicted. Their male genitalia (Figs 1C, 1D), external morphology, colour and pattern are quite distinct and indicate that the two species belong to different species groups. The types of *S. parva* Saunders and *S. subversicolor* are conspecific with specimens of *S. decemguttata*. I conclude that *S. decemguttata* Gory is a valid species. *S. parva* Saunders is its senior synonym and *S. subversicolor* Carter its junior synonym.

Barker (1979, p. 20) stated that *S. hostilis* Blackburn 1892 was a synonym of *S. sagittaria* L. & G. 1837. I have examined a further series of specimens attributable to both forms. Male genitalia (Figs 1G, 1H) are slightly different. The apices of the parameres and median lobe are more pointed in *S. hostilis* than in *S. sagittaria* and the apophysis of the basal piece narrower in *S. hostilis* than in *S. sagittaria*. *S. hostilis* is smaller than *S. sagittaria* with red margins to the elytra which *S. sagittaria* does not have. *S. sagittaria* is found only on the coastal plain W.A., while *S. hostilis* is found inland in lower rainfall areas in W.A. Because of these differences I conclude that *S. hostilis* is a good species.

Barker (1979, p. 16) listed *S. marginicollis* Saunders 1868 as a synonym of *S. cyanipes* Saunders 1868. *S. marginicollis* is the eastern member of a species pair and *S. cyanipes* 1868 is the western member. In *S. marginicollis* the undersurface and femora are red-brown, the tibia and tarsi are blue; in *S. cyanipes* the undersurface is dark blue with the edges of the abdominal segments variably red. The legs are blue. Male genitalia differ: the parameres of *S. marginicollis* (Fig. 1J) are broader than those of *S. cyanipes* (Fig. 1J), the apophysis of the basal piece of *S. marginicollis* is broader and the median lobe is thicker. Because the species are geographically separate, have colour and pattern differences and the male genitalia are different I consider *S. marginicollis* Saunders to be a valid species.

S. sieboldi L. & G. 1837 (Fig. 4F) was first synonymised by Kerremans (1902) with *S. amphicroa* (Boisduval) 1835. Carter (1916) decided that *S. amphicroa* was a synonym of *S. crenata* (Donovon) 1805 and also *S. sieboldi* (Carter 1924, 1929). Obenberger (1928) and Carter (1931) synonymised *S. sieboldi* with *S. amphicroa* and Carter (1931) listed *S. crenata* as a separate species. Obenberger (1933, 1934) then resurrected *S. sieboldi* as a valid species. Carter (1940) in an article castigating Obenberger, stated twice that *S. sieboldi* was a synonym of *S. amphicroa*. The type of *S. sieboldi* L. & G. is located in the Hope Museum, Oxford (Barker, 1979) and is very distinctive. Although the elytral markings are similar to those of *S. crenata*, *S. sieboldi* is a smaller species and has a bright blue area in the middle of the green-sided pronotum. The pronotum of *S. crenata* is entirely blue. The male genitalia of *S. sieboldi* (Fig. 1K) and external morphology are distinct from those of *S. crenata* (Fig. 1L) and indicate that the two species belong in different species groups. I conclude that *S. sieboldi* is a valid species.

Barker (1979, p. 15) listed *S. parvula* Deuquet 1956 as a synonym of *S. canaliculata* Blackburn 1892. I have examined the male holotype of *S. canaliculata* and find that it is a typical member of the *S. sexplagiata* Gory species group, with triangular genitalia and loss of tarsal pads on tarsomeres of legs 2 and 3. It is most likely a small specimen of *S. erythroptera* (Boisduval) 1835. *S. parvula* Deuquet 1956 (Fig. 1M) has elongate male genitalia distinct from the triangular genitalia of the *S.*

aetaplagiata species group (Figs 1P-1S) and in the male type has tarsal pads present on all tarsomeres of legs 2 and 3. I conclude *S. parvula* Deuquet to be a valid species. It is a small lycid mimic and is found in central N.S.W. and in southern Queensland.

Carter (1916, 1929) synonymised *S. timida* Kerremans 1898 (Fig. 4G) with *S. flavovaria* Saunders 1871, the latter being a replacement name for *S. flavopicta* L. & G. 1837. Carter (1931) was unable to decide whether *S. timida* was a synonym of *S. assimilis* Hope 1846 or of *S. puerilis* Kerremans 1898, despite the fact that *S. timida* has priority over *S. puerilis*. Obenberger (1934) listed *S. timida* as a synonym of *S. puerilis*. Barker (1979, p. 14) listed both species as synonyms of *S. assimilis* Hope. Subsequently Barker (1980, p. 7) established *S. assimilis* as a synonym of *S. australasiae* L. & G. 1837 and then listed *S. timida* and *S. puerilis* as junior synonyms of *S. australasiae* L. & G. I have re-examined the appropriate types and find that *S. timida* and *S. puerilis* are synonymous and are a separate species from *S. australasiae*. The male genitalia of *S. timida* (Fig. 1N) are quite different from that of *S. australasiae* (Fig. 10) and place it in the *S. cruentata* (Kirby) species group. These genitalia are slender with a broad median lobe and narrow parameres which are indented at the sides near the apex. Male genitalia of *S. cruentata* are slightly more indented at the sides forming a ledge, the median lobe is broader and blunter. *S. timida* occurs in the Blue Mts. N.S.W. and in the Stanthorpe area, Qld. *S. cruentata* occurs from Gippsland, Vic. to south-eastern Qld. It is a slightly smaller species than *S. timida*, has red elytra and very deep blue markings. *S. timida* is dark green with yellow elytra. I consider *S. timida* Kerremans to be a valid species and *S. puerilis* Kerremans to be its senior synonym.

Carter (1916, 1929, 1931) listed *S. cruentata* (Kirby) as a synonym of *S. vegeta* Hope. As this did not follow the rules of priority and agreeing that they were synonymous. Barker (1979) listed *S. vegeta* Hope as a synonym of *S. cruentata* (Kirby). I have re-examined the type of *S. vegeta* Hope and have found it distinct from specimens of *S. cruentata* (Kirby) identified by reference to a coloured transparency of the type. *S. cruentata* has red elytra and deep blue markings; the ends of the pre-medial fascia are expanded anteriorly and

posteriorly to the basal and lateral margins. *S. vegeta* has orange elytra with black markings and green or blue-green pronotum and undersurface. The ends of the pre-medial fascia are not expanded anteriorly and posteriorly, but the inferior edge of the fascia reaches the lateral margin. Male genitalia are similar except that the median lobe in *S. cruentata* is broader and blunter than in *S. vegeta*. In S. Aust. *S. vegeta* occurs on Kangaroo Isd, Yorke and Eyre Peninsulas, and in Victoria in the Ararat district.

Carter (1916, 1929, 1931) and Barker (1979) synonymised *S. triramosa* Thomson with *S. simulata* L. & G. I have found that the colour and pattern of a distinct species from South Australia and Victoria conforms with a coloured photograph of the type of *S. triramosa* Thomson lodged at the MNHN, Paris. The male genitalia of both species are illustrated in Figs 3Q, 3R. The parameres of *S. triramosa* are slender and are abruptly rounded at the apex compared with those of *S. simulata* which are slightly wider and gradually rounded at the apex. On the basis of differences in the male genitalia and colour and pattern of the body I consider *S. triramosa* Thomson to be a good species. It is re-described and illustrated (Fig. 7G).

Carter (1919) and Barker (1979) synonymised *S. leai* Carter with *S. dimidiata* Carter (Fig. 6I). I have examined types of *S. dimidiata* in NMVA and of *S. leai* in SAMA and compared male genitalia (Figs 3D, 3E). Those of *S. dimidiata* are larger than those of *S. leai*. In *S. dimidiata* the parameres are narrower at the apex and the apophysis of the basal piece broader than in *S. leai*. *S. dimidiata* (Fig. 6I) is a larger broader species than *S. leai*. The dorsal surface is a brassy green colour and there are two yellow basal spots, one on each elytron. *S. leai* is a smaller narrower species, the dorsal surface is blue-green or blue and there are no yellow basal spots. *S. leai* occurs in Tasmania and *S. dimidiata* only from mountains in Vic. and N.S.W. On the basis of these differences I consider *S. leai* Carter to be a valid species.

Variety elevated to specific status

S. deserti Blackburn 1892 was described as a variety of *S. atricollis* Saunders 1869. Male genitalia of a specimen attributable to *S. deserti* and those of *S. atricollis* (Figs 1E, 1F) are different. *S. atricollis* has narrow, elongate parameres, gradually widened from the base

and rounded off just before the apex. The median lobe has sides angling straight away from the apex. The apophysis of the basal piece widens out towards the end and is spoon-shaped. *S. deserti* has short, thick para-

meres, widened out half way from base to apex with the sides rounded off just before the apex. The apex of the median lobe is pointed, the sides round away then straighten. The apophysis of the basal piece narrows towards

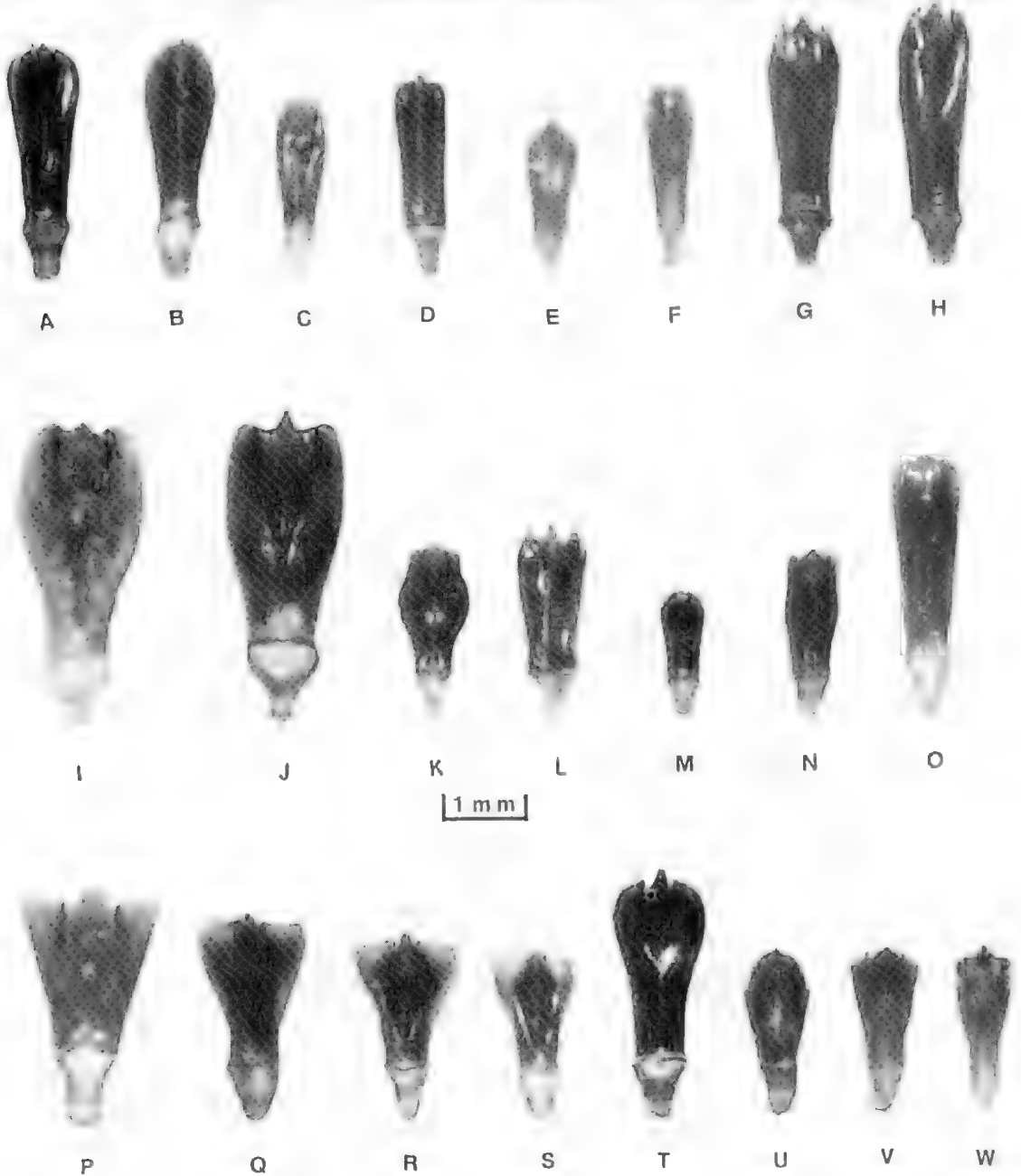


Fig. 1. Photomicrographs of male genitalia of *Stigmodera* (*Castiarina*) species: A. *S. broomensis*, B. *S. biguttata*, C. *S. decemguttata*, D. *S. versicolor*, E. *S. deserti*, F. *S. atricollis*, G. *S. hostilis*, H. *S. sagittaria*, I. *S. marginicollis*, J. *S. cyanipes*, K. *S. sieboldi*, L. *S. crenata*, M. *S. parvula*, N. *S. timida*, O. *S. australasiae*, P. *S. tigris*, Q. *S. frauciana*, R. *S. cornishi*, S. *S. vulgaris*, T. *S. thurmerac*, U. *S. powelli*, V. *S. flavopicta*, W. *S. alpestris*.

the end. *S. deserti* is an elongate species and each elytron has a wide marginal spine. *S. atricollis* is comparatively shorter. It has a sharp, elongate marginal spine on each elytron. On the basis of differences in the male genitalia and external morphology I consider *S. deserti* Blackburn a valid species. It is redescribed and illustrated (Fig. 4E).

Barker (1979) listed *S. callubriensis* Carter (1931) as being described on p. 367, but in reality the description is printed on p. 386 in the journal. In reprints of the article the description was printed on p. 367, presumably to save space.

The abbreviations used in the text for museum and private collections (Watt, 1979) are as follows:

AHQA Mr A. Walford-Huggins, Mt Molloy, Qld. AMSA Australian Museum, Sydney. ANIC Australian National Insect Collection, C.S.I.R.O., Canberra. EAQA Mr E. E. Adams, Edungalba, Qld. GWNA Mr G. Williams, Lansdowne, N.S.W. JHQA Mrs J. Harslett, Amiens, Qld. JTNA Mr J. R. Turner, Hill End, N.S.W. KCWA Mr and Mrs K. Carnaby, Wilga, W.A. MNHN Museum Nationale d'Histoire Naturelles, Paris. MPWA Mr M. Powell, Mr M. Golding and Mr T. M. S. Hanlon, Attadale, W.A. PIMA Department of Primary Industry, Mareeba. QMBA Queensland Museum, Brisbane. RMBB L'Institut Royal des Sciences Naturelles de Belgique, Brussels. RTVA Mr R. G. Thompson, Elwood, Vic. SAMA South Australian Museum, Adelaide. WADA Western Australian Department of Agriculture, South Perth. WAMA Western Australian Museum, Perth. ZMHU Museum of Natural Science, Humboldt University, Berlin.

***Stigmodera (Castiarina) tigris* sp. nov.**

FIGS 1P, 4H

Holotype. ♂, 5 km W Petford, Qld, 28.i.1978, R. I. Storey, ANIC.

Paratype. ♂, Desailly Range, 98.6 km N Mareeba, Qld, 387 m, 13.ii.1973, J. G. Brooks, 'Iron Bark', ANIC.

Colour. Head and pronotum black with bronze reflections. Antennae, scutellum, undersurface and legs black. Elytra yellow with following black markings: basal margin; post-medial fascia concave forwards; mark covering pre-apex and apex. Undersurface hairs silver, collar hairs yellow.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum closely punctured, small basal fovea extending forwards as glabrous impressed line almost to apex, basal notches represented by glabrous area on each side, closer to margin than to

middle, area between each and lateral margin slightly depressed; apical margin straight, basal margin bisinuate; laterally parallel-sided at base, rounded out to widest point before middle, rounded and narrowed to apex. Scutellum scutiform, faintly punctured, excavate. Elytra punctate-striate, intervals convex, more so at apex than base, intervals 1–5 from suture moderately punctured, smooth, the rest heavily punctured and rough; laterally angled out from base, rounded at humeral callus, concave until after middle, rounded to bispinose apex; both spines small, margin indented between, apices diverging slightly.

Undersurface closely punctured, moderately hairy, hairs short. S_7 (Sternite 7) truncate in male. Male tarsal pads: on legs 2 & 3 absent on tarsomeres 1–3, each replaced by double median spine.

Size. Male, 13.3×4.8 mm (2).

Male genitalia, Fig. 1P. Largest in *S. sexplagiata* Gory group, typically triangular-shaped. The apices of the parameres are slightly concave and the median lobe broad and sharp.

Remarks. Largest member of *S. sexplagiata* Gory group (Fig. 4I). The elytral markings differ from all other species. The specific name is derived from *tigris* L. tiger, alluding to the colour.

***Stigmodera (Castiarina) frauciana* sp. nov.**

FIGS 1Q, 4J.

Holotype. ♂, Pine Creek, Bundaberg, Qld, 14.xii.1975, H. Frauca, ANIC.

Allotype. ♀, same data as holotype, ANIC.

Colour. Head, antennae, pronotum black with blue-green reflections. Scutellum green. Elytra yellow with red margins and following black markings: narrow basal margin; pre-medial fascia expanded anteriorly over humeral callus and posteriorly obliquely to lateral margin; broad post-medial fascia expanded anteriorly at end, touching margin and enclosing yellow spot between two fascia; small pre-apical spade-shaped mark extending down suture and covering apex and spines, all marks connected down suture. Undersurface blue-green. Legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum closely punctured, basal fovea extending forwards to anterior margin as deep impressed line, basal notch on each side closer to margin than to middle; apical margin projecting for-

wards in middle, basal margin bisinuate; laterally parallel-sided at base, rounded at middle to apex. Scutellum scutiform, few punctures, excavate in midline. Elytra punctate-striate, scutellary and 3rd interval from suture raised, convex and glabrous, other intervals flat in middle, convex at base, intervals 1 and 2 punctured and wrinkled, subglabrous, rest deeply punctured and rough; laterally sharply angled out from base, rounded at humeral callus (widest part), concave until after middle then rounded and tapered to bispinose apex; marginal spine larger than sutural spine, margin rounded and indented between, apices diverging. Undersurface closely punctured, moderately hairy, hairs medium length. S_7 truncate in male, rounded in female. Male tarsal pads: on legs 2 and 3 absent on tarsomeres 1-3, each replaced by double median spine.

Size. Male, 9.9×3.7 mm (1)

Female, 10.5×4.0 mm (1)

Male genitalia. Fig. 1Q. Typical triangular-shape of the *S. sexplagiata* Gory group. The apices of the parameres are almost straight and the median lobe is narrow and pointed. The apophysis of the basal piece is broad.

Remarks. A very distinct member of the *sexplagiata* group. The apical spines are small and the ends of the two fascia coalesce forming two yellow spots in the middle of the elytra, the only species in the group where this occurs. Named after Mr H. Frauca, Bundaberg, Qld.

***Stigmodera (Castiarina) cornishi* sp. nov.**

FIGS 1R, 4K.

Holotype. ♂, Tallering Station, Pindar, W.A. 4.ix.1976. R. P. McMillan, WAMA.

Allotype. ♀, same data as holotype, WAMA.

Paratypes. 7 ♂ & 4 ♀, same data as holotype, SAMA, WAMA. ♀, 146 km E Norseman, W.A. 3.x.1977. E. Baker, SAMA; ♂ Balladonia Stn, W.A. on *Myoporum platycarpum*, 25.x.1980, S. Barker & P. G. Kempster, SAMA; ♀, 25 km W Balladonia, W.A. *Eremophila paisleyi*, 17.x.1982, S. Barker, P. G. Kempster & H. Vanderwoude, SAMA; 2 ♂ & ♀, 18 km S-W Derallinya ruin, Balladonia district, W.A. *Eremophila scaparia*, 22.x.1982. S. Barker, P. G. Kempster & H. Vanderwoude, SAMA & WAMA.

Colour. Head, pronotum and undersurface dull bronze. Antennae, legs, scutellum dark blue. Elytra red with following black markings with blue reflections: basal margin; pre-medial fascia which may be broken into central spot and two lateral broad spots, one in middle of each elytron; post-medial fascia reaching

margin, projecting forwards on suture; spade-shaped mark covering apex, all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured median sulcus, muzzle short. Antennae: segments 1-4 obconic, 5-11 toothed. Pronotum closely punctured, basal fovea extending forwards as median impressed line; apical margin straight with well defined collar, basal margin barely bisinuate; laterally rounded from base, widest before middle, rounded to apex. Scutellum scutiform, without punctures, excavate. Elytra, punctate-striate, intervals convex, more so at apex than base, punctured and wrinkled more so at sides than in middle; laterally angled out from base, rounded at humeral callus concave then rounded after middle to bispinose apex; marginal spine small, sutural spine minute, margin rounded and indented between, apices diverging. Undersurface with close shallow punctures, hairy, hairs moderately long. S_7 truncate in male, rounded and indented in middle in female. Male tarsal pads: on legs 2 and 3 absent on tarsomeres 1-3, each replaced by double median spine.

Size. Males, $9.2 \pm 0.22 \times 3.5 \pm 0.07$ mm (11). Females, $9.5 \pm 0.39 \times 3.7 \pm 0.18$ mm (8).

Male genitalia. Fig. 1R. Typical triangular-shaped of the *S. sexplagiata* Gory group. The apices of the parameres are almost straight and the median lobe is narrow and pointed. The apophysis of the basal piece is narrowed.

Remarks. This species belongs in the *S. sexplagiata* group. It is closest to *S. vulgaris* Carter (Figs 1S, 4L) but differs in having larger genitalia, the apices of the elytra are rounded and the apical spines small. In *S. vulgaris* the apices are more pointed and the spines larger. *S. cornishi* has a bronze pronotum and undersurface while *S. vulgaris* has a blue pronotum and undersurface. Named after Mr W. Cornish, formerly of Tallering Station, Pindar, W.A.

***Stigmodera (Castiarina) thurmerae* sp. nov.**

FIGS 1T, 7C.

Holotype. ♂, 35 km S Diemals, W.A. 31.xii.1981 on *Grevillea nematophylla*, S. Wilson, WAMA

Allotype. ♀, 40 km S Diemals, W.A. 31.xii.1981. M. Powell, WAMA.

Paratypes. 5♂, same data as holotype, MPWA; ♂, Murchison District, W.A. Elder Expedition, SAMA.

Colour. Head blue. Antennae bronze. Scutellum and undersurface dark blue. Legs dark blue except bases of femora bronze. Elytra pale yellow with the following dark blue markings: basal margin; post-medial fascia reaching margin, projecting forwards in middle of anterior edge, posterior edge concave, projecting forwards and backwards on suture; pre-apical mark covering whole apex, all marks connected down suture. Undersurface hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae compressed; segments 1-3 obconic, 4-11 toothed. Pronotum with close shallow punctures, no basal fovea, variable median impressed line; apical margin projecting forwards strongly in middle, basal margin bisinuate; laterally parallel-sided at base, rounded less than halfway to middle then tapered to apex. Scutellum cordiform without punctures, excavate in middle of anterior margin. Elytra punctate-striate, intervals convex with shallow punctures; laterally angled outwards from base, rounded at humeral callus, concave until after middle, then rounded to hispidose apex; apical spine larger than sutural, margin rounded and indented between, apices slightly diverging, apical margin sub-serrate. Undersurface shallowly punctured, lightly haired, S_7 indented in middle in both sexes. Male tarsal pads: on legs 2 & 3 reduced on tarsomeres 1-3, small single median spine present at base of the reduced pads.

Size. Males, $15.0 \pm 0.22 \times 5.2 \pm 0.11$ mm (6). Females, 16.7 ± 5.3 mm (1).

Male genitalia. Fig. 1T. The parameres are elongate, broadened out and rounded at the apex. The median lobe is narrow and the apophysis of the basal piece is broad.

Remarks. The colour and pattern of this species are similar to those of *S. longicollis* Saunders. However, *S. longicollis* has rounded sides to the pronotum while in *S. thurmerae* the sides of the pronotum are tapered and the pronotum is relatively longer than in other species. The tarsomeres of males resemble the shape of those found in males of *S. quadrfasciata* Saunders and *S. uptoni* Barker. *S. thurmerae* cannot be grouped with these or any other species at this time. Named after Ms Jenni Thurmer, artist. South Australian Museum.

***Stigmodera (Castiarina) powelli* sp. nov.**

FIGS 1U, 5A.

Holotype. ♂, 33 km S Coolgardie, W.A. 14.xi.1980. M. Powell, WAMA.

Allotype. ♀, 48 km S Coolgardie, W.A. 14.xi.1980. T. M. S. Hanton, WAMA.

Paratypes. ♂, 48 km S Coolgardie, W.A. 14.xi.1980. M. Powell, SAMA; ♀, same data as allotype. MPWA; 2 ♀, S. Aust., SAMA.

Colour. Head green at base, blue-green muzzle. Antennae blue-green. Pronotum laterally blue-green, green in middle of each side, black with bronze margin in centre. Scutellum black with bronze reflections. Elytra pale yellow with following black markings: narrow basal margin; triangular spot at base on each side with blunt apex pointing to suture representing an incomplete basal fascia; post-medial fascia reaching margin convex forwards, concave backwards; mark covering pre-apex and apex, last two marks connected down suture. Undersurface and legs blue-green. Hairs silver.

Shape and sculpture. Head closely punctured, broad shallow median sulcus, muzzle short and broad. Antennae: segments 1-3 obconic, 4 3-toothed, 5-11 toothed. Pronotum closely punctured, very small basal fovea extending forwards as thin glabrous line until after middle; apical margin straight, basal margin bisinuate; laterally parallel-sided at base, round and broadest before middle, tapered to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex with shallow punctures; laterally angled out from base, rounded at humeral callus, concave rounded after middle to hispidose apex; marginal spine short and thick, sutural spine minute, margin indented between, apices slightly diverging. Undersurface with close shallow punctures, very short sparse hairs, S_7 rounded in both sexes. Male tarsal pads: on legs 2 & 3, reduced on tarsomeres 1 & 2.

Size. Males, $8.8 \pm 0.5 \times 3.2 \pm 0.2$ mm (2). Females, $9.4 \pm 0.5 \times 3.5 \pm 0.2$ mm (4).

Male genitalia. Fig. 1U. The sides of the parameres are notched as in *S. flavoptera* (Boisduval) (Fig. 1V) but there is a greater distance between the notch and the apex of the parameres. The median lobe in *S. powelli* is rounded whereas in *S. flavoptera* it is angled at the tip.

Remarks. Member of *S. flavoptera* group because of similarities in male genitalia and external morphology. Named after Mr M. Powell, Attadale, W.A.

Stigmodera (Castiarina) alpestris sp. nov.

FIGS 1W, 6D.

Holotype. ♂, Upper Tumut Gorge, N.S.W. 5.ii.1957, 1477 m, J. G. Filmer, QMBA.

Allotype. ♀, Mt Kosciuszko, N.S.W. 27.ii.1951, F. F. Wilson, NMVA.

Paratypes. ♂, same data as holotype, QMBA; ♂, Lob's Hole, Tumut R., iv.1955, 523 m, Sedlacek, ANIC; 2 ♂, same data as allotype, NMVA & SAMA; ♀, Mt Kosciuszko, N.S.W. ii.1951, M. W. Mules, NMVA; 2 ♂, Mt Buffalo, Vic. 13.i.1955 & 24.ii.1955, AN, NMVA; ♂, no data, NMVA.

Colour. Head, antennae, pronotum, scutellum, undersurface and legs bright green with gold reflections. Elytra deep yellow with following dark green markings: basal margin; broad pre-medial fascia reaching lateral margin enclosing basal yellow spot and one on margin; broad post-medial fascia; mark covering pre-apex and apex; all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1-4 obconic, 5-11 toothed. Pronotum closely punctured, very small slit-like basal fovea projecting to middle as thin glabrous line, then to margin as impressed line; apical margin projecting forwards in middle, basal margin bisinuate; laterally rounded from base to apex, widest before middle. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals flat in middle, convex at apex, with shallow punctures; laterally angled out from base, rounded at humeral callus, concave then rounded to hispinose apex; marginal spine thick and blunt, sutural spine minute, margin indented and rounded between, apices slightly diverging. Undersurface with shallow punctures, very short hairs. S_7 truncate in both sexes. Male tarsal pads: on legs 2 & 3 reduced on tarsomeres 1 & 2.

Size. Males, $9.1 \pm 0.33 \times 3.2 \pm 0.1$ mm (8). Females, 9.0×3.4 mm (2).

Male genitalia. Fig. 1W, lateral edges of parameres indented near apex. Median lobe with sharp apex, broadening further down.

Remarks. Member of *S. cruentata* (Kirby) species group because of similarities in male genitalia and external morphology. The two Victorian specimens and one from Mt Kosciuszko have a peacock blue pronotum. The specific name is derived from *alpestris* L., of high mountains.

Stigmodera (Castiarina) dingoensis sp. nov.

FIGS 2A, 5B.

Holotype. ♂, 107 km N Dingo, Qld 10.i.1979, E. E. Adams & S. Barker, SAMA I 21 138.

Paratypes. 3 ♂ & 2 ♀, same data as holotype, SAMA.

Colour. Head, antennae, scutellum and pronotum bright green with yellow or reddish reflections. Undersurface and legs bright green. Elytra ivory with thin dark brown basal margin.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4 3-toothed, 5-11 toothed. Pronotum closely punctured, small narrow basal fovea, basal notches obscure; apical margin projecting in middle, basal margin bisinuate; laterally rounded from base, widest before middle, rounded and narrowed to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals slightly convex, lightly punctured; laterally angled outwards from base, rounded at humeral callus, slightly concave, rounded after middle then narrowed to hispinose apex; marginal spine larger than sutural, margin rounded and indented between, apices diverging. Undersurface closely punctured, moderately hairy, hairs short. S_7 truncate in both sexes. Male tarsal pads: on legs 2 & 3 absent on tarsomeres 1-3, each replaced by single median spine.

Size. Males, $7.3 \pm 0.26 \times 2.7 \pm 0.09$ mm (4). Females, 7.6×3.0 mm (2).

Male genitalia. Fig. 2A. Same general shape as in *S. dispar* Blackburn (Fig. 2B), but the median lobe is more acutely angled at the apex than in *S. dispar* and the apophysis of the basal piece is narrower.

Remarks. The colour, body shape and genitalia are similar to those of *S. dispar*, which is a larger species and males do not have modified tarsal pads. Because of the last feature I am unable to place this species in a species group. The species name is derived from that of the type locality.

Stigmodera (Castiarina) hypocrita sp. nov.

FIGS 2C, 5C.

Holotype. ♂, Mt Spec, Qld 9.i.1966, E. E. Adams, SAMA I 21 139.

Allotype. ♀, Kuranda, Qld xii.1961, J. G. Brooks, ANIC.

Paratypes. Qld: 2 ♂, Mt Spec, 6 & 9.i.1964, E. E. Adams, FAQA; ♂, Mt Spec, i.1966, J. G. Brooks, AHMA; ♀, Mt Spec, 12.i.1966, J. G. Brooks,

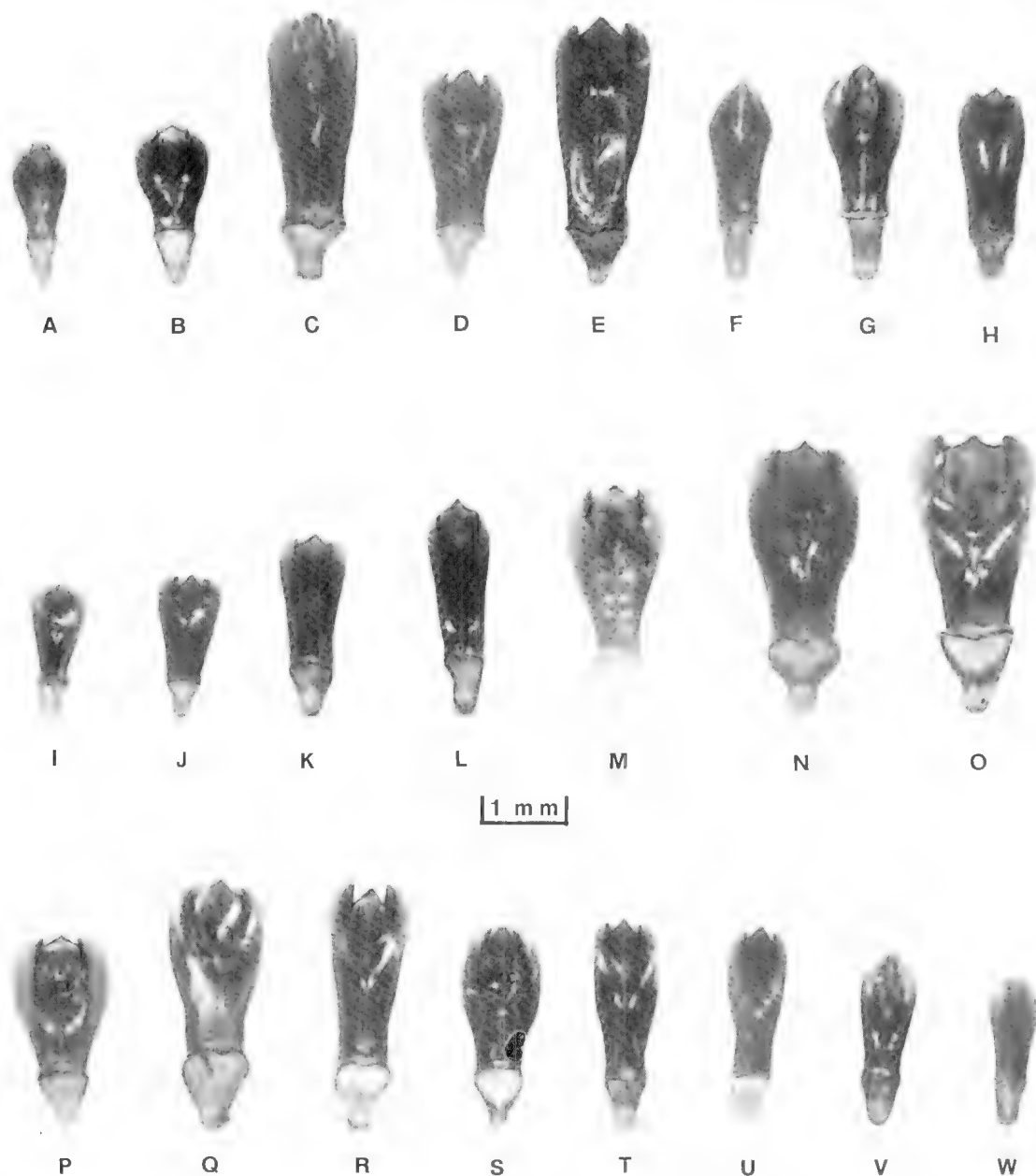


Fig. 2. Photomicrographs of male genitalia of *Stigmodera* (*Castiarina*) species: A. *S. dingoensis*, B. *S. dispar*, C. *S. hypocrita*, D. *S. flavosignata*, E. *S. goldingi*, F. *S. furtiva*, G. *S. scalaris*, H. *S. eneabba*, I. *S. subtestacea*, J. *S. testacea*, K. *S. marginata*, L. *S. kershawi*, M. *S. yellowdinensis*, N. *S. alexandri*, O. *S. cruenta*, P. *S. storeyi*, Q. *S. armstrongi*, R. *S. supergrata*, S. *S. grata*, T. *S. forresti*, U. *S. elderi*, V. *S. goodingi*, W. *S. aurolimbata*.

AHMA; 2♂, 19 & 16 km W Paluma, Ewan Rd, Mt Spec, 10.i.1968, & 8.i.1969, J. G. Brooks, ANIC; ♂, Windsor Rd, via Mt Carbine, 11.ii.1978, R. I. Storey, PIMA; ♂, 42 km N Mt Carbine, 7.i.1978, R. I. Storey, PIMA; ♂, 9 km W Mt Molloy, 30.xii.1981, J. & D. Gardner, SAMA; ♂, Kuranda, French collection, NMVA.

Colour. Head and antennae black. Pronotum orange-brown with the following black markings: fascia before middle, ends extended downwards, connected to mark along basal margin by thin median line; forward extension from basal notches on each side, not

reaching ends of pre-medial fascia. Scutellum black. Elytra red-brown with following black markings: basal margin; elongate vitta on each humeral callus; large post-medial mark covering pre-apical and apical area, this can be connected to the vittae, anterior border connected to this mark down suture, expanded in middle to diamond-shaped mark. Undersurface red-brown with sutures and edges of abdominal segments black, legs black with blue reflections. Hairs silver.

Shape and sculpture. Head closely punctured, with very short sparse hairs, median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum closely punctured, basal fovea extending forwards to middle as glabrous line, basal notches closer to margin than middle; apical margin straight, basal margin bisinuate; laterally parallel-sided at base, rounded before middle, then tapered to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex more so at base and apex than in middle, deeply punctured and wrinkled; laterally angled out from base, rounded at humeral callus, concave then rounded after middle to spineless apex; apices rounded and diverging, apical margin subserrate. Undersurface with shallow punctures, sparse very short hair. S_7 rounded in both sexes.

Size. Males, $12.3 \pm 0.28 \times 5.0 \pm 0.14$ mm (9). Females, 14.5×6.0 mm (3).

Male genitalia. Fig. 2C. Overall size larger than in *S. flavosignata* MacLeay (Fig. 2D). The parameres are parallel-sided towards the apices, the median lobe is narrower and blunter than in *flavosignata* and the apophysis of the basal piece is broader.

Remarks. This species belongs in the *S. flavosignata* species group. It is a larger species with black and brown markings whereas *S. flavosignata* has red and blue markings. Both species appear to be bug mimics but the models have not been identified. The specific name is derived from *hypocrita* L., dissembler.

***Stigmodera (Castiarina) goldingi* sp. nov.**

FIGS 2E, 5D.

Holotype. ♂, 20 km N Coolgardie, W.A. 20.x.1979, M. Golding, WAMA.

Paratype. ♂, 20 km N Coolgardie, W.A. 20.x.1979, M. Powell, MPWA.

Colour. Head blue-green. Antennae: segments 1 & 2 blue-green, rest bronze. Pronotum blue,

green in middle, pale red at lateral margins. Scutellum blue. Elytra pale red with following black markings with blue reflections; narrow basal margin; vitta at each humeral callus and an expanded spot on suture, all remnants of a pre-medial fascia; post-medial fascia reaching margin expanded forwards and backwards at suture and in middle of each side; mark covering whole pre-apex and apex, all marks connected down suture. Undersurface: sternum blue; abdomen blue base, rest red; legs blue with blue-green tarsi. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum, close shallow punctures, small basal fovea extending forwards as thin glabrous line to middle then as impressed line almost to margin; apical margin projecting forwards broadly in middle, basal margin barely bisinuate; laterally parallel-sided at base, rounded out and bulbous before middle, tapered to apex. Scutellum scutiform, without punctures, glabrous, excavate in midline. Elytra punctate-striate, intervals convex, more so at apex than in middle and punctured, those at sides more heavily than in middle; laterally parallel-sided at base angled outwards, rounded at humeral callus, concave, rounded after middle and tapered to spineless apex; apical-sutural margin indented, apices diverging. Undersurface with close shallow punctures, moderately hairy, hairs medium length. S_7 rounded in male.

Size. Males, 13.8×5.4 mm (2).

Male genitalia. Fig. 2E. The sides of the parameres are nearly parallel before the apex and at the apex are rounded. The median lobe is broad and the apex is wide angled. The apophysis of the basal piece is broad.

Remarks. I am unable to place *S. goldingi* in a species group. Named after Mr M. Golding, Sydney.

***Stigmodera (Castiarina) furtiva* sp. nov.**

FIGS 2F, 5E.

Holotype. ♂, Tammin, W.A. H. W. Brown, ANIC.

Allotype. ♀, Konnongorring, W.A. 1.xii.1956, S. Barker, SAMA 1 21 143.

Paratypes. W.A.: 2 ♀, Red Bluff, W.A. 10.xii.1971, N. McFarland, ANIC; ♂, Tammin, H. W. Brown, ANIC; ♂ & ♀, Beverly, E. F. du Boulay, SAMA; ♂, ANIC; ♂, Bolgart, 19.xi.1978, M. Powell, MPWA; 2 ♂, no data, SAMA; 2 ♂ & ♀, Mullewa, WAMA; 3 ♂ & 3 ♀, 56 km N-E Wubin, 18.x.1977, K. T. Richards, WADA; 4 ♂ & ♀, 60 km N-E

Wubla, 18.x.1977, K. T. Richards, WADA; 4 ♂ & 3 ♀, 64 km N-E Wubin, 18.x.1977, K. T. Richards, WADA; 2 ♂, 72 km N-E Wubin, 22.xi.1977, K. T. Richards, WADA; ♂, Lake Bryde, 23.xi.1972, K. T. Richards, WADA; 3 ♂ & ♀, Lake Grace, 23.xi.1972, K. T. Richards, WADA; 13 ♂ & 4 ♀, East Hyden, 24.xi.1977, K. T. Richards, WADA; ♂, 25 km S Lake King, 15.xi.1980, T. M. S. Hanlon, MPWA; ♀, 110 km E Southern Cross, 20.x.1979, D. Knowlton, MPWA; ♀ Lake Ningham, WAMA.

Colour. Head and antennae bronze. Pronotum bronze with or without blue reflections at margins. Scutellum, undersurface and legs deep blue. Elytra orange with following black markings: narrow basal margin; pre-medial fascia not reaching margin and pointing forwards at each end; post-medial fascia reaching margin projecting forwards in middle from anterior edge on each side; pre-apical mark connected along suture to post-medial fascia and spines. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1-4 obovate, 5-11 toothed. Pronotum closely punctured, small basal fovea, basal notches on each side closer to margin than to middle; projecting forwards slightly in middle of apical margin, basal margin barely bisinuate; laterally angled inwards from base then rounded before middle, rounded and narrowed to apex. Scutellum scutiform, punctured, anterior margin excavate. Elytra punctate-striate, intervals rounded more so at apex than base, faint punctures; laterally angled out slightly from base, rounded at humeral callus, concave then rounded after middle and tapered to hispid apex; spines equal, margin rounded and indented between. Undersurface closely punctured, moderately hairy, hairs short, S_7 truncate in male, faintly bilobed in female.

Size. Males, $9.9 \pm 0.13 \times 3.5 \pm 0.06$ mm (40). Females, $10.3 \pm 0.21 \times 3.7 \pm 0.1$ mm (20).

Male genitalia. Fig. 2F. The genitalia are curved upwards along the longitudinal axis. At the sides the parameres are bulbous before the apex. At the apex the parameres and the median lobe are narrowed. The apophysis of the basal piece is elongate and narrowed. Similarities with the genitalia of *S. scalaris* (Boisduval) (Fig. 2G) are the shape of the median lobe and the curve along the long axis. *S. scalaris* however, has rounded not bulbous sides to the parameres and the median lobe is broader.

Remarks. Belongs in *S. scalaris* species group on the basis of similarities in male genitalia and external morphology. This species has been confused with others because of similarities in elytral markings. The specific name is derived from *furtiva* L., concealed.

Stigmodera (*Castiurina*) *deserti* Blackburn
1892

FIGS 1E, 4E.

Stigmodera deserti Blackburn, 1892, p. 36, Oberberger, 1934: p. 699.

Stigmodera atricollis Blackburn, 1892, p. 36. Carter 1931: p. 364, 1940: p. 387.

Holotype. Not located.

Colour. Head, antennae, pronotum, scutellum, undersurface and legs dark blue. Elytra yellow with following dark blue markings: narrow basal margin; pre-medial fascia expanded forwards in middle of anterior edge and projecting forwards and backwards at end not reaching margin, in some specimens reduced to a spot on each humeral callus and one on suture; post-medial fascia reaching margin, projecting forwards in middle of anterior edge, concave backwards; mark covering apex and spines, all marks connected down suture. Hairs silver.

Shape and sculpture. Head close shallow punctures, shallow median sulcus, eyes bulbous, muzzle short. Antennae compressed; segments 1-3 obovate, 4-11 toothed. Pronotum shallowly punctured, minute basal fovea; projecting forwards broadly in middle of apical margin, basal margin almost straight; laterally parallel-sided at base then broadened and rounded after middle and narrowed to apex. Scutellum scutiform, without punctures, flat. Elytra punctate-striate, intervals flat in middle convex at sides and apex; laterally slightly angled out from base rounded at humeral callus, straight until after middle, rounded and tapered to pre-apex then rounded to hispid apex; marginal spine larger than minute sutural spine, margin angled and indented between, apices diverging, apical margin sub-serrate. Undersurface with shallow punctures, sparse short hairs, S_7 truncate in male, round in female.

Size. Males, 6.9 ± 2.4 mm (4). Female, 6.5×2.0 mm (1).

Specimens examined. W.A.: ♂, Yampie Gorge, 26.vii.1967, F. H. Uther Baker, SAMA; ♂, Carnarvon, 24.viii.1975, R. P. McMillan, SAMA; ♂ & ♀, Lake Austin, H. W. Brown, SAMA; ♂, Murchison, SAMA; ♂, Willemoort Gorge, 23.viii.1972, S. M. Wain, WAMA.

Remarks. Belongs in *S. atricollis* Saunders species group, but is a much smaller species and male genitalia differ (p. 142).

***Stigmodera* (Castiarina) *eneabba* sp. nov.**

FIGS 2H, 5F.

Holotype. ♀, Eneabba, W.A. 10.x.1970, K. & E. Carnahy, SAMA.

Allotype. ♀, 60 km E Hyden, 18.x.1981, D. Knowles, WAMA.

Paratypes. W.A.: 2 ♂, Eneabba, K. & E. Carnahy, KCWA; ♂, 98 km E Southern Cross, Boorabbin Rocks N. P., 3.x.1981, R. Thorpe, MPWA.

Colour. Head, antennae, pronotum, scutellum, undersurface and legs bright green. Elytra yellow with following black markings: narrow basal margin; either small spot on each humeral callus and larger pair close together on either side of suture, or with one of either pair missing, remnants of pre-medial fascia; post-medial fascia reaching margin, projecting forwards on suture; mark covering apex and spines, connected along suture to post-medial fascia. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle very short. Antennae compressed: segments 1–3 obconic, 4–11 toothed. Pronotum closely punctured, minute basal fovea extending forwards as glabrous line to middle, basal notches represented by glabrous areas on each side; apical margin projecting forwards in middle, basal margin bisinuate; laterally gently angled outwards until after middle then rounded to apex. Scutellum scutiform, glabrous, flat. Elytra punctate-striate, intervals slightly convex at base more so at apex, deeply punctured at sides, shallowly in middle; laterally angled outwards from base, rounded at humeral callus concave then rounded after middle, narrowed to bispinose apex; marginal spine sharp, sutural spine minute, margin rounded and indented between. Undersurface hairs very short and sparse. S_7 broadly truncate in male, narrowly truncate in female.

Size. Males, $10.8 \pm 0.13 \times 3.5 \pm 0.07$ mm (4). Female, 12.8×4.3 mm (1).

Male genitalia. Fig. 2H. The parameres are rounded and narrow towards the apex while those of *S. atricollis* Saunders (Fig. 1F) broaden out before they round off at the apex. The apex of the median lobe is sharp and broadly angled while the apophysis of the basal piece is slightly broader than that in *atricollis*.

Remarks. This species belongs in the *atricollis* species group as the genitalia show similarities to *atricollis* and the external morphology is similar. They are quite distinct as apart from the elytra, the rest of the body is green while in *atricollis* it is blue. The specific name is derived from the name of the type locality.

***Stigmodera* (Castiarina) *subtestacea* sp. nov.**

FIGS 2I, 5G.

Holotype. ♂, Piawanning, W.A. 28.i.1951, R. P. McMillan, WAMA.

Allotype. ♀, same data as holotype, WAMA.

Paratypes. W.A.: 2 ♂, same data as holotype, SAMA; ♂ & ♀, Perth, xi.1953, E.S., SAMA; ♂, 16 km S Borden, 27.ii.1956, J. A. L. Watson, SAMA; 3 ♂, Lake Grace, SAMA; ♂, Lake Bryde, 16.xii.1974, K. T. Richards, WADA; ♂, 20 km N Hatters Hill, 23.i.1975, K. T. Richards, WADA; 3 ♂ & ♀, Lake Grace, 20.j.1930, H. W. Brown, NMVA; ♂ & 3 ♀, Lake Grace, H. W. Brown, NMVA; 4 ♂, Lake Grace, H. W. Brown, WAMA; 3 ♂ & ♀, Cranbrook, 4.ii.1954, A. Douglas, WAMA; ♂, Dedari, H. W. Brown, WAMA; 2 ♂ & ♀, Piawanning, WAMA; ♂, Kakerin, WAMA; 3 ♂ & ♀, Kojonup, 31.xii.1978, R. P. McMillan, WAMA; 3 ♂, Kojonup, 1.i.1979, R. P. McMillan, WAMA; 4 ♂ & 3 ♀, Kojonup, 3.i.1979, R. P. McMillan, WAMA. S. Aust.: ♂, no data, SAMA.

Colour. Head brown. Antennae, pronotum, scutellum, undersurface and legs testaceous with transparent spotting. Elytra the same, most specimens with brown apical mark. Hairs silver.

Shape and sculpture. Head closely punctured, shallow median sulcus, muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum closely punctured, small basal fovea, basal notches on each side, closer to margin than to middle; apical margin straight, basal margin bisinuate; laterally rounded from base to apex, widest before middle then narrowed to apex. Scutellum scutiform, small, without punctures, flat. Elytra punctate-striate, intervals convex; laterally slightly angled out from base, rounded at humeral callus then straight until after middle, round and tapered to bispinose apex; marginal spine larger than sutural, margin rounded and indented between, apices diverging. Undersurface closely and shallowly punctured, sensory bristles on either side of midline on meso- and metasternum in male, rest virtually hairless except for ventral collar. S_7 truncate in male, rounded in female.

Size. Males, $7.6 \pm 0.09 \times 2.7 \pm 0.03$ mm (36). Females, $7.9 \pm 0.21 \times 2.7 \pm 0.07$ mm (12).

Male genitalia. Fig. 2I. The sides of the parameres are angled outwards near the apex and then rounded off. The median lobe is sharp and broadly angled and the apophysis of the basal piece is slightly elongate compared with that of *S. testacea* Saunders (Fig. 2J).

Remarks. In an earlier paper (Barker, 1979) I erroneously placed 9 of the above specimens in the new species *S. crockerae*. This is a smaller species than *S. crockerae* and resembles *S. testacea* Saunders more closely but is not costate. *S. testacea*, *S. crockerae*, *S. subtestacea* and *S. nigriceps* Barker seem to be members of a ring species complex. They are all cryptic as they mimic the colour of the eucalypt flowers on which they are found. The locality label on the single male in the SAMA collection designated from S. Aust. may be incorrect. The specific name is derived from sub L., under *testacea*.

***Stigmodera (Castiarina) marginata* sp. nov.**

FIGS 2K, 5H.

Holotype. ♂, Sellick's scrub, Aldinga, S. Aust. 24.x.1978, *S. Barker*, SAMA I 21 144.

Allotype. ♀, Sellick's scrub, Aldinga, S. Aust. 31.x.1978, *P. Christy*, SAMA I 21 145.

Paratypes. S. Aust.: 15 ♂, same data as holotype, SAMA; ♂, same data as allotype, SAMA; 3 ♂, S-W River, Kangaroo Isd, 23.xi.1967, *S. Barker*, SAMA; ♂, Edillilie, Eyre Peninsula, 7.xii.1968, *N. McFarland*, SAMA; ♀, Upper Torrens Gorge, 4.xi.1967, *S. Barker*, SAMA; ♂ & ♀, Sellick's scrub, Aldinga, 27.x.1972, *S. Barker*, SAMA; ♂ & ♀, Flinders Chase, Kangaroo Isd, 27.xi.1972, *S. Barker*, SAMA; ♂, Pt Lincoln, 16.xi.1974, *S. Barker*, SAMA; ♂, Uraidla, 26.xii.1974, *A. Wells*, SAMA; ♂, Sellick's scrub, Aldinga, 4.xi.1978, *S. Barker*, SAMA; ♂ & 2 ♀, Flinders Chase, Kangaroo Isd, 29.xi.1978, *S. Barker*, SAMA; 3 ♂ & ♀, Pt Lincoln, *Blackburn*, SAMA; ♀, Murray Bridge, SAMA; ♀, Kangaroo Isd, *J. G. O. Tepper*, SAMA; ♀, Lucindale, SAMA; ♀, SAMA, 2 ♀, Aust. *W. White*, SAMA; ♂, xi.1901, French, SAMA; ♂ & ♀, no data, SAMA.

Colour. Head blue. Antennae green. Pronotum blue. Scutellum, undersurface and legs deep blue. Elytra pale yellow with red lateral margins and the following black markings with blue reflections: narrow basal margin; pre-medial fascia expanded forwards to humeral callus not touching margin; post-medial fascia touching margin projecting forwards on suture; mark covering apex and spines, all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle short. Antennae: segments 1–4 obconic, 5–11 toothed. Pronotum closely punctured, shallow basal fovea;

apical margin straight, basal margin bisinuate; laterally parallel-sided at base, rounded before middle, then tapered to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex, more so at base than apex, punctured and wrinkled progressively more so from suture to margin; laterally angled outwards from base, rounded at humeral callus, concave then rounded after middle and tapered, angled inwards just before bispinose apex; marginal spine sharp, sutural spine minute, margin rounded and indented between, apices diverging, most of margin punctured and rough. Undersurface closely punctured, moderately long dense hair. S_7 truncate in both sexes.

Size. Males, $10.3 \pm 0.13 \times 3.8 \pm 0.05$ mm (33). Females, $10.5 \pm 0.23 \times 4.2 \pm 0.12$ mm (13).

Male genitalia. Fig. 2K. The sides of the parameres are angled out more than in *S. kershawi* Carter (Fig. 2L) and the apophysis of the basal piece is shorter. The median lobe is sharp and the sides angled at the same degree as in *S. kershawi*.

Remarks. This species belongs to the *S. bella* Saunders species group of which *S. kershawi* Carter is also a member. *S. kershawi* has red elytra and occurs in high country in Vic. and N.S.W. *S. marginata* has yellow elytra with red margins and occurs at low altitude in South Australia. The specific name is derived from *marginatus* L. enclose with a border and alludes to the red margin.

***Stigmodera (Castiarina) yellowdinensis* sp. nov.**

FIGS 2M, 5I.

Holotype. ♂, Yellowdine, W.A. 8.i.1980, *M. Golding*, WAMA.

Allotype. ♀, 8 km E Yellowdine, W.A. 13.xi.1980, *M. Powell*, WAMA.

Paratype. ♂, same data as holotype, SAMA.

Colour. Head, antennae, pronotum, scutellum and legs bronze. Elytra yellow with following black markings with blue reflections: narrow basal margin; oblique spot on each humeral callus and post-medial spot towards margin but not touching it, elongate spot at same level on suture; small mark covering apex, heavy mark from scutellum down suture not reaching middle. Undersurface: sternum bronze; abdomen testaceous. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1–3 obconic, 4–11 toothed. Pronotum

closely punctured, small basal fovea extending forwards to middle as thin glabrous line, basal notches represented by small glabrous areas; apical margin projecting forwards in middle, basal margin barely bisinuate; laterally parallel-sided at base, rounded to widest point before middle, tapered to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex and punctured; laterally parallel-sided at base, angled outwards then rounded at humeral callus, concave, rounded after middle to bispinose apex; apical spine larger than sutural, margin rounded and indented between apices slightly diverging, apical margin sub-serrate. Undersurface with shallow punctures, short hairs, S_7 rounded in males, truncate in females.

Size. Males, 12.0×4.4 mm (2). Female, 13.9×5.4 mm (1).

Male genitalia. Fig. 2M. The sides of the parameres are parallel towards the apex where they are rounded. There is a small point in the apex of the median lobe and the sides are then angled outwards. In *S. alexandri* Carter (Fig. 2N) the sides of the parameres are rounded before the apex and there is a small point at the apex of the median lobe but the sides have a greater outward angle. The apophysis of the basal piece of *S. yellowdinensis* is comparatively wider than that of *S. alexandri*. Both species belong in the *S. cruenta* L. & G. species group (Fig. 2O).

Remarks. Belongs in *cruenta* species group on basis of similarities in male genitalia, external morphology and testaceous abdomen. Closest to *S. alexandri* Carter. The specific name is derived from the name of the type locality.

***Stigmodera* (Castiarina) *storeyi* sp. nov.**

FIGS 2P, 5J.

Holotype ♂, Desailly Ra, 101 km N Mareeba, Qld 25.i.1973, A. & M. Walford-Huggins, QMBA.

Allotype ♀, Mt Carbine, Qld 7.i.1981, S. Barker, SAMA.

Colour. Head, pronotum and sternum dull purple with blue reflections. Antennae and scutellum blue-green. Legs: femora blue-green; dorsal tibia purple, ventral tibia blue-green; tarsi blue-green. Abdomen testaceous. Elytra pale yellow with following markings: narrow blue-green basal margin; elongate black mark on each humeral callus angled outwards towards margin; narrow elongate pre-medial black mark on suture; narrow black post-

medial fascia not reaching margin; black mark covering apex, last two connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, deep median sulcus, muzzle short. Antennae: segments 1–3 oboenic, 4–11 toothed. Pronotum closely punctured, small deep basal fovea surrounded by glabrous area without punctures, basal notches closer to margin than middle, glabrous patch without punctures above basal angle; projecting forwards in middle of apical margin, basal margin barely bisinuate; laterally parallel-sided at base, then rounded to widest part before middle, rounded and narrowed to apex. Scutellum scutiform, few punctures, flat. Elytra punctate-striate, intervals convex, more so at apex than base, punctured and progressively more wrinkled from suture to margin; 3 pairs of striae closer together than others so that intervals 4, 6 & 8 are narrower than rest; laterally slightly angled out from base, rounded at humeral callus, concave then rounded after middle to bispinose apex; marginal spine larger than sutural, margin rounded and indented between apices diverging, apical margin sub-serrate. S_7 truncate in male, rounded and indented in middle in female.

Size. Male, 11.8×3.9 mm (1). Female, 11.8×4.5 mm (1).

Male genitalia. Fig. 2P. The sides of the parameres are rounded and expanded outwards towards the apex. The apex of the median lobe is sharp and the sides are angled outwards. The apophysis of the basal piece is thick and the whole nedaegus is short and thick.

Remarks. This species belongs in *S. cruenta* L. & G. species group on the basis of male genitalia, testaceous abdomen and external morphology. Distinguished from other members by alternately normal and narrow striae on elytra. Named after Mr R. I. Storey, Mareeba, Qld.

***Stigmodera* (Castiarina) *armstrongi* sp. nov.**

FIGS 2Q, 6A.

Holotype ♂, Bogan R., N.S.W. J. Armstrong, QMBA.

Allotype ♀, Minnie Downs Stn. S. AusL L.C. SAMA I 21 146.

Paratypes. ♀, same data as holotype, JHQA; ♀, same data as holotype, ANIC; ♂ & ♀, Nockatunga, Qld 13.xi.1949, E. F. Riek, ANIC, SAMA; ♂, 19 km N Tennant Creek, N.T. C. Roche, AHQA.

Colour. Head, antennae, pronotum, scutellum, sternum and legs green, blue-green or blue,

Abdomen testaceous except at sides of base which usually has an elongate mark of blue or blue-green. Elytra pale yellow with the following markings: narrow basal margin green or blue-green in some specimens, extending short distance down suture; single dark blue post-medial spot in middle of each elytron; broad dark blue semi-circular mark concave forwards covering apical region, the sides reduced in some specimens. Hairs silver.

Shape and sculpture. Head with close shallow punctures, broad median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum with shallow punctures, sparse and smaller in middle than at sides, very small basal fovea extending forwards as glabrous line of variable length, basal notches closer to margin than to middle; projecting forwards in middle of apical margin, basal margin almost straight; laterally parallel-sided at base, rounded and bulbous before middle, rounded and narrowed to apex. Scutellum scutiform, narrow and glabrous. Elytra punctate-striate, intervals convex, more so at base and apex than middle, lightly punctured and wrinkled; laterally angled out slightly from base, rounded at humeral callus, concave then rounded after middle, rounded and narrowed to bispinose apex; marginal spine small and blunt but larger than sutural spine, margin rounded and indented between, apices diverging, apical margin sub-serrate. Undersurface with close shallow punctures, very sparse short hairs. S_7 truncate in male, rounded in female.

Size. Males, 13.2×4.9 mm (3). Females, 14.3×5.3 mm (4).

Male genitalia. Fig. 2Q. The sides of the parameres are parallel after the middle, then rounded towards the apex. The median lobe has a pointed apex and the sides are angled outwards. The apophysis of the basal piece is broad.

Remarks. Belongs to *S. cruenta* L. & G. species group on the basis of similarities in male genitalia, external morphology and testaceous abdomen. Named after Mr J. Armstrong, formerly of Callubri Station, Nyngan, N.S.W.

***Stigmodera* (Castiarina) supergrata sp. nov.**

FIGS 2R, 6B.

Holotype. ♂, Moe, Vic. 20.xi.1944, C. G. L. Gooding, ANIC

Allotype. ♀, Moe, Vic. 5.xi.1955, C. G. L. Gooding, ANIC.

Paratypes. Vic.: ♂ & 5 ♀, Moe, 15.xi.1947, 15.x.1944, 18.xi.1954, 5.xi.1945, C. G. L. Gooding, ANIC; ♀, Rokeby, 21.xi.1958, C. G. L. Gooding, EAQA; ♂, Moorooduc, 13.xi.1920, SAMA; ♀, Healesville, xi.1922, J. L. Dixon, ANIC; ♂ & ♀, Drouin Stn, 6.xii.1958, C. G. L. Gooding, ANIC; ♂, 21 km Shady Crk, Willow Grove Rd, 5.xi.1963, C. G. L. Gooding, ANIC; 2 ♂, 3.2 km S, Willow Grove, 26.xi.1966, C. G. L. Gooding, ANIC; ♂, Rokeby, xi.1975, C. Elton, ANIC; ♀, Hall's Gap, 14.xi.1950, LeSneuf, SAMA; ♀, Oakleigh, SAMA; ♂ & 2 ♀, 12 km N Hall's Gap, 7.xi.1979, G. & T. Williams, GWNA; 3 ♂ & ♀, Brisbane Hills, 22.x.1972, R. G. Thompson, RTVA; 2 ♂, Brisbane Hills, 29.x.1972, R. G. Thompson, RTVA; ♂ & ♀, Tea Tree Crk, 9.xi.1949, B. Given, NMVA; ♂ & ♀, Mt Dandenong, 12.xii.1948, F. E. Wilson, NMVA; ♀, Belgrave, 19.xii.1923, L. B. Thorn, NMVA; ♂ & ♀, Emerald, 19.xi.1903, J.K., NMVA; ♂, Grampians, 15.xi.1945, NMVA; ♂, Grampians, xi.1942, NMVA; ♀, Croydon, NMVA; ♀, Berwick, NMVA; ♀, Warburton, i.1902, NMVA; ♀, Dandenong Ranges, 20.iv.1922, NMVA, N.S.W.; ♀, 1 km W Mt Wilson, Bell Rd, 4.xii.1977, G. & T. Williams, GWNA.

Colour. Head dark blue, Antennae green. Pronotum dark blue, lateral margins red. Scutellum dark blue. Elytra red with following dark blue markings: broad pre-medial fascia extending from basal margin almost to middle not touching margin; broad post-medial fascia touching margin; mark covering pre-apical and apical region, all marks connected down suture. Undersurface blue-green. Hairs silver.

Shape and sculpture. Head closely and shallowly punctured, deep median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum closely but shallowly punctured; basal fovea extending forwards to middle as thin glabrous impressed line, small basal notch on each side, closer to margin than middle; projecting forwards in middle of apical margin, basal margin almost straight; laterally slightly angled outwards from base, rounded before middle, then rounded and narrowed to apex. Scutellum scutiform, without punctures, excavate. Elytra punctate-striate, intervals convex, more so at apex than base, deeply punctured and wrinkled; laterally angled outwards from base, rounded at humeral callus, concave then rounded after middle and narrowed to spineless apex; apices rounded and diverging. Undersurface with close shallow punctures, moderately hairy, hairs short. S_7 slightly rounded in male, rounded in female.

Size. Males, $13.0 \pm 0.32 \times 4.8 \pm 0.13$ mm (17). Females, $13.6 \pm 0.16 \times 5.2 \pm 0.08$ mm (25).

Male genitalia. Fig. 2R. Sides of parameres straight from the middle and angled outwards.

abruptly rounded then flattened at the apex. The apex of the median lobe is pointed and the sides angled outwards. The apophysis of the basal piece is broad. They differ from the genitalia of *S. grata* Saunders (Fig. 2S) which are smaller, the sides of the parameres are angled inwards from the middle and the apophysis of the basal piece is narrow.

Remarks. This species belongs in *S. grata* Saunders species group but is larger than *grata*, the male genitalia are different and the elytral colour darker red. The specific name is derived from *super* L. over, *grata*.

***Stigmodera* (*Castiarina*) *forresti* sp. nov.**

FIGS 2T, 6C

Holotype. ♂, 10 km W Gaseoyne Junction, W.A. 22.ix.1980, S. Barker & D. J. Williams, WAMA

Allotype. ♀, same data as holotype, WAMA.

Paratypes. 12 ♂ & 14 ♀, same data as holotype (WAMA & SAMA); ♂, 89 km N Camarvon, W.A. 22.ix.1980, S. Barker & D. J. Williams, SAMA.

Colour. Head bronze with purple reflections at the base, large yellow frontal spot, mouthparts blue-green. Antennae blue-green. Pronotum bronze with purple reflections and yellow lateral margins. Scutellum dark blue with purple reflections. Elytra pale yellow with dark orange margins two intervals wide and the following dark blue markings: narrow basal margin; pre-medial fascia, not reaching lateral margin, ends extending forwards obliquely over humeral callus; post-medial fascia reaching margin; mark covering whole of pre-apex and apex, all marks connected down suture. Under-surface yellow. edges of sutures on meso-sternum blue-green, blue-green spot at sides of 3 basal abdominal segments, edges of abdominal segments blue-green or testaceous. Legs blue-green. Hairs silver.

Shape and sculpture. Head with shallow punctures, no median sulcus, muzzle short. Antennae: segments 1-4 obconic, 5-11 toothed. Pronotum closely punctured; small basal fovea, basal notches on each side closer to margin than middle; projecting forwards slightly in middle of apical margin, basal margin barely bisinuate; laterally parallel-sided at base, then rounded to apex, widest in middle. Scutellum scutiform, without punctures, slightly wrinkled, excavated in middle. Elytra punctate-striate, intervals convex more so at apex than base, punctured and wrinkled; laterally angled out for short distance from

base, rounded at humeral callus (widest point), concave and rounded after middle, rounded and narrowed to trispinose apex; middle spine largest, margin rounded between outer and middle spine, rounded and indented between middle and sutural spine. Under-surface with very shallow punctures, sparse short hair, S_7 truncate in male, faintly bilobed in female.

Size. Males, $11.0 \pm 0.3 \times 3.9 \pm 0.07$ mm (14). Females, $12.2 \pm 0.23 \times 4.4 \pm 0.1$ mm (15).

Male genitalia. Fig. 2T. The sides of the parameres are parallel after the middle then rounded to the apex. The apex of the median lobe is pointed and the sides angled outwards. The apophysis of the basal piece is of median width. The genitalia of *S. elderi* Blackburn (Fig. 2U) are of the same length but with narrower apices to the parameres.

Remarks. All specimens were collected on the flowers of *Verticordia forresti*. Belongs in *S. elderi* Blackburn species group because of similarities in male genitalia and external morphology. *S. forresti* is a larger species than *S. elderi*. The basal elytral colour of *S. elderi* is red. Named after the late Lord Forrest.

***Stigmodera* (*Castiarina*) *goodingi* sp. nov.**

FIGS 2V, 6E.

Holotype. ♂, Ward's Mistake, N.S.W. xii.1952, A. Champion, ANIC.

Allotype. ♀, same data as holotype, ANIC.

Paratypes. 4 ♂ & 4 ♀, same data as holotype (3 ♂ & 3 ♀ ANIC, ♂ & ♀ SAMA).

Colour. Head, antennae, pronotum, under-surface and legs green with gold reflections. Scutellum bright green. Elytra testaceous with following markings: narrow bright green basal margin; elongate angled spot at humeral callus, outer part bright green, inner black; single post-medial black spot on each elytron, closer to margin than suture; thick bright green border continuous with basal margin surrounding scutellum and running down suture to apex covering spines, thin outer edge black. Hairs silver.

Shape and sculpture. Head very closely punctured, deep median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum very closely punctured, small basal fovea, basal notches closer to margin than middle; anterior margin straight, basal margin bisinuate; laterally parallel-sided until before middle, then rounded and nar-

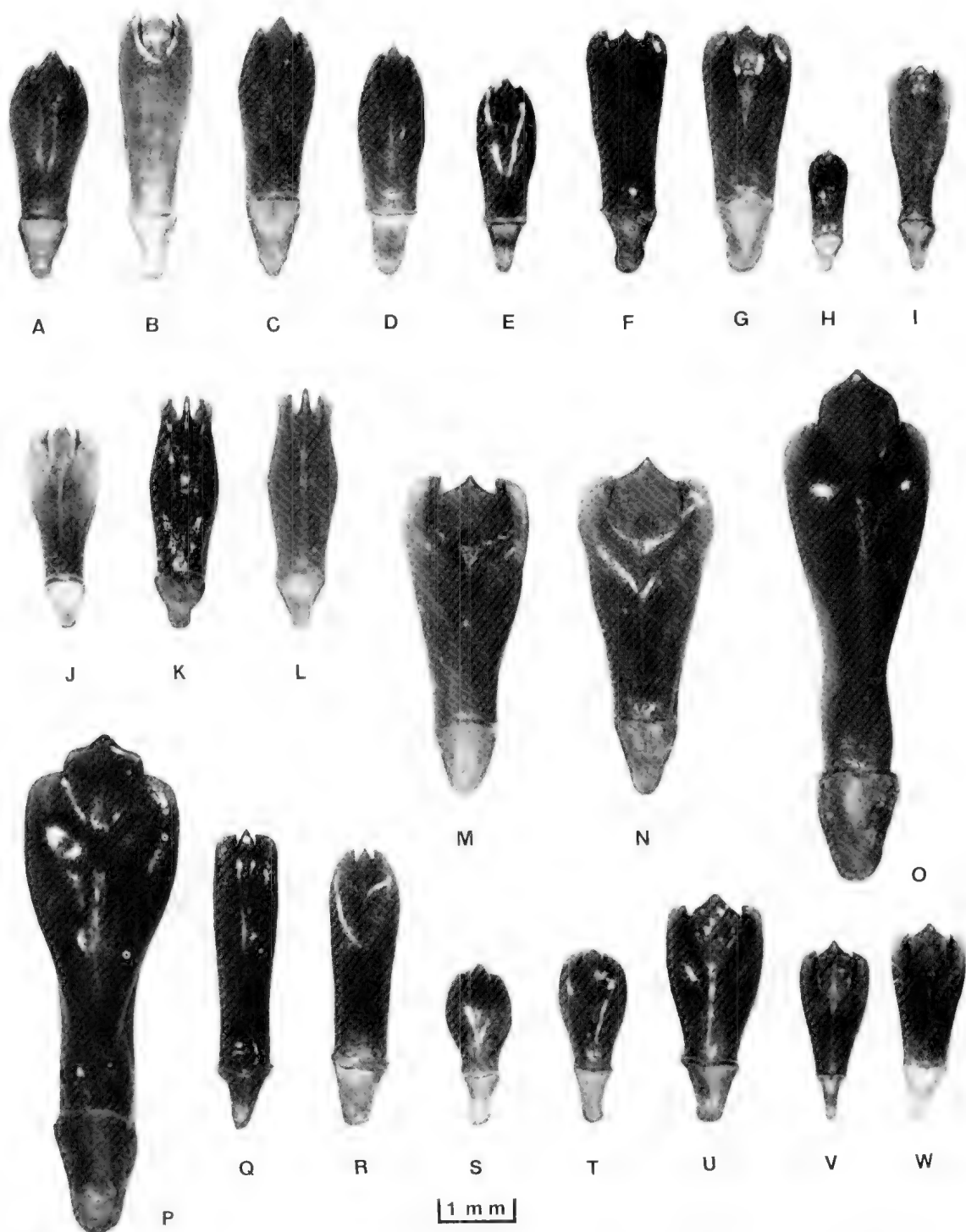


Fig. 3. Photomicrographs of male genitalia of *Stigmodera* (*Castiarina*) species: A. *S. kalbarri*, B. *S. trifasciata*, C. *S. boldensis*, D. *S. dimidiata*, E. *S. leai*, F. *S. variegata*, G. *S. coerulipes*, H. *S. pseuderythroptera*, I. *S. hanloni*, J. *S. octomaculata*, K. *S. subvicina*, L. *S. distincta*, M. *S. scintillata*, N. *S. variopicta*, O. *S. semicincta*, P. *S. jeanae*, Q. *S. triramosa*, R. *S. simulata*, S. *S. chinnocki*, T. *S. cupricauda*, U. *S. turneri*, V. *S. euclae*, W. *S. convexa*.

rowed to apex. Scutellum scutiform, punctured, excavate in midline. Elytra punctate-striate. 9th interval from suture raised over entire length, margin flattened, intervals lightly punctured and slightly wrinkled; laterally angled out slightly from base, rounded at humeral callus concave then rounded after middle and tapered, rounded again just before bispinose apex; marginal spine larger than sutural, margin rounded and indented between apices diverging. Undersurface closely punctured, sparse short hair. S_7 truncate in male, rounded and indented in female.

Size. Males, $8.4 \pm 0.2 \times 3.2 \pm 0.1$ mm (5). Females, $8.9 \pm 0.2 \times 3.5 \pm 0.1$ mm (5).

Male genitalia. Fig. 2V. The sides of the parameres are angled outwards from the basal piece upwards then rounded near the apex with sharp points at the apices. The median lobe is thin and pointed at the apex. The apophysis of the basal piece is broad. The genitalia of *S. aurolimbata* Carter (Fig. 2W) are similar but smaller and the median lobe is even more pointed at the apex and the apophysis of the basal piece is not as broad at the base but rounded outwards just before the apex.

Remarks. Superficially like *S. hilaris* Hope but larger and male genitalia differs. Grouped with *S. aurolimbata* Carter on the basis of male genitalia and external morphology. Named after the late Mr C. G. Gooding.

***Stigmodera* (Castiarina) *kalbarri* sp. nov.**

FIGS 3A, 6F.

Holotype. ♂, 44 km E Kalbarri, W.A. 26.ix.1980, S. Barker & D. J. Williams, WAMA.

Allotype. ♀, 46 km E Kalbarri, W.A. 26.ix.1980, S. Barker & D. J. Williams, WAMA.

Paratypes. 3 ♂, same data as holotype, SAMA & WAMA; ♂ & 2 ♀, same data as allotype, SAMA & WAMA; ♂, Kalbarri, W.A. 10.x.1979, M. Golding, MPWA; ♂, 13 km N Murchison River, W.A. 10.x.1979, M. Powell, MPWA; 2 ♀, Northampton, W.A. 28.viii.1971 & 31.viii.1973, K. T. Richards, WADA.

Colour. Head, antennae, scutellum, undersurface and legs green with gold reflections. Pronotum green with gold reflections and in some specimens a dull bronze patch in middle. Elytra orange with following black markings with blue-green reflections: narrow basal margin; pre-medial fascia, not reaching lateral margin and angled forwards over humeral callus; post-medial fascia reaching margin projecting forwards and backwards along

suture, pre-apical spade-shaped mark also covering apex and spines, all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle very short. Antennae compressed; segments 1–3 obovate, 4–11 toothed. Pronotum closely punctured, minute basal fovea extending forwards as glabrous line to middle, basal notches on each side represented by broad glabrous area; apical margin projecting forwards in middle, basal margin barely bisinuate; laterally parallel-sided at base, rounded after middle and narrowed to apex. Scutellum scutiform, without punctures, excavate along anterior margin. Elytra punctate-striate, intervals flat at base, convex at apex, punctured and wrinkled; laterally angled out from base, rounded at humeral callus, concave then rounded after middle and narrowed to bispinose apex; large marginal spine, minute sutural spine, margin rounded and indented between apices diverging, apical margin subserrate. Undersurface hairs long and sparse. S_7 broadly truncate in male, narrowly truncate and indented in female.

Size. Males, $11.8 \pm 0.4 \times 4.3 \pm 0.14$ mm (8). Females, $12.8 \pm 0.82 \times 4.7 \pm 0.29$ mm (4).

Male genitalia. Fig. 3A. The sides of the parameres are rounded after the middle and bulge outwards before they are rounded off to the apex. The median lobe is pointed and the sides are acutely angled. The apophysis of the basal piece is of medium width. The genitalia of male *S. trifasciata* L. & G. (Fig. 3B) are longer, the sides of the parameres are parallel after the middle then rounded to the apices, the apex of the median lobe is pointed but the sides are not acutely angled. The apophysis of the basal piece is of medium width and slightly elongate.

Remarks. Belongs in *S. trifasciata* L. & G. species group because of similarities in male genitalia and external morphology. All specimens taken on 26.ix.1980 were captured on the flowers of *Thryptomene denticulata* (F. Muell.) Benth. The species name is derived from the name of the type locality.

***Stigmodera* (Castiarina) *holdensis* sp. nov.**

FIGS 3C, 6G.

Holotype. ♂, Wernhley, W.A. H. W. Brown, SAMA.

Allotype. ♀, same data as holotype, SAMA.

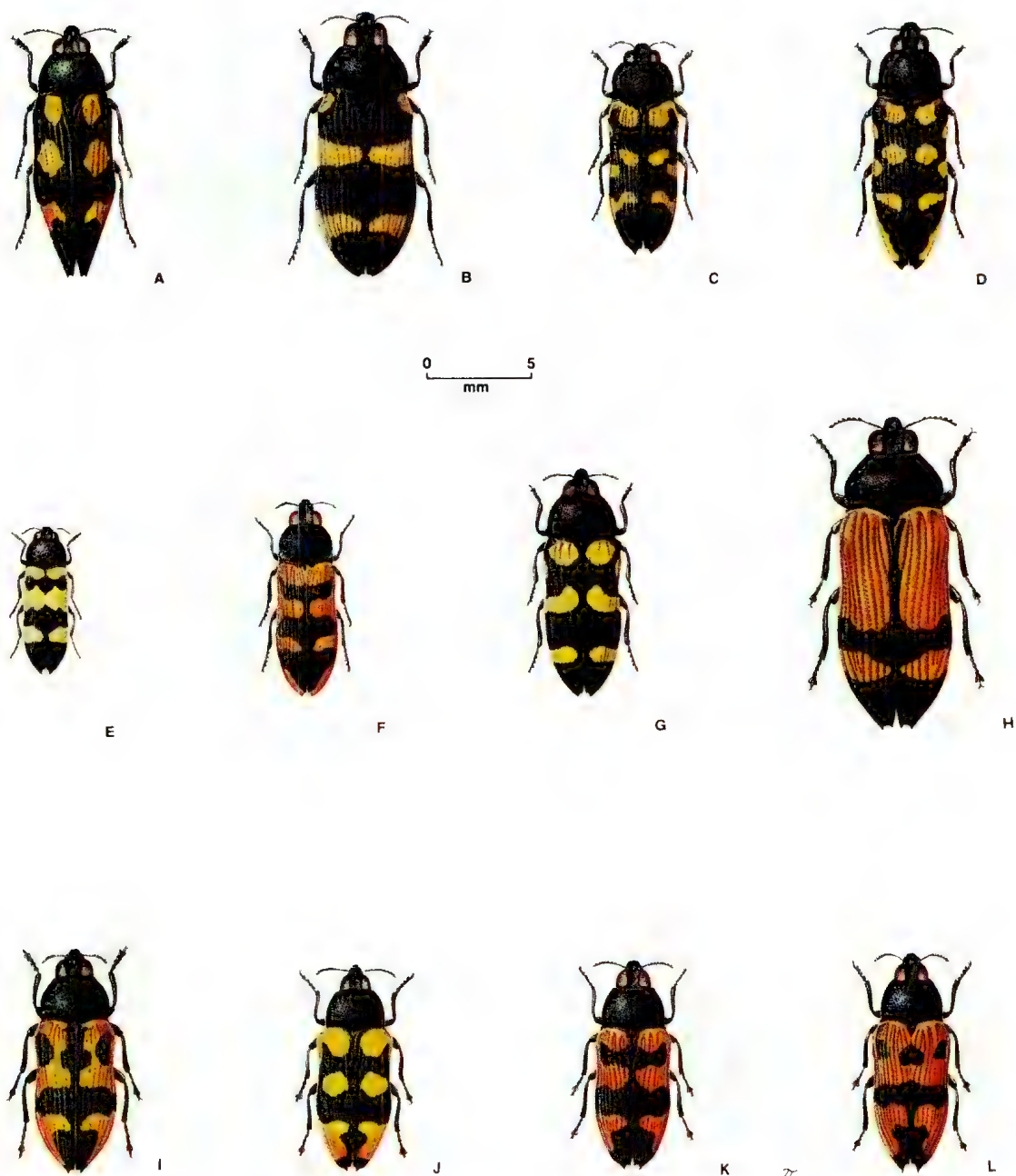


Fig. 4. A. *Stigmodera delicatula* Kerremans, B. *S. subvicina* sp. nov., C. *S. decemguttata* L. & G., D. *S. versicolor* L. & G., E. *S. deserti* Blackburn, F. *S. sieboldi* L. & G., G. *S. timida* Kerremans, H. *S. tigris* sp. nov., I. *S. sexplagiata* Gory, J. *S. frauciana* sp. nov., K. *S. cornishi* sp. nov., L. *S. vulgaris* Carter.

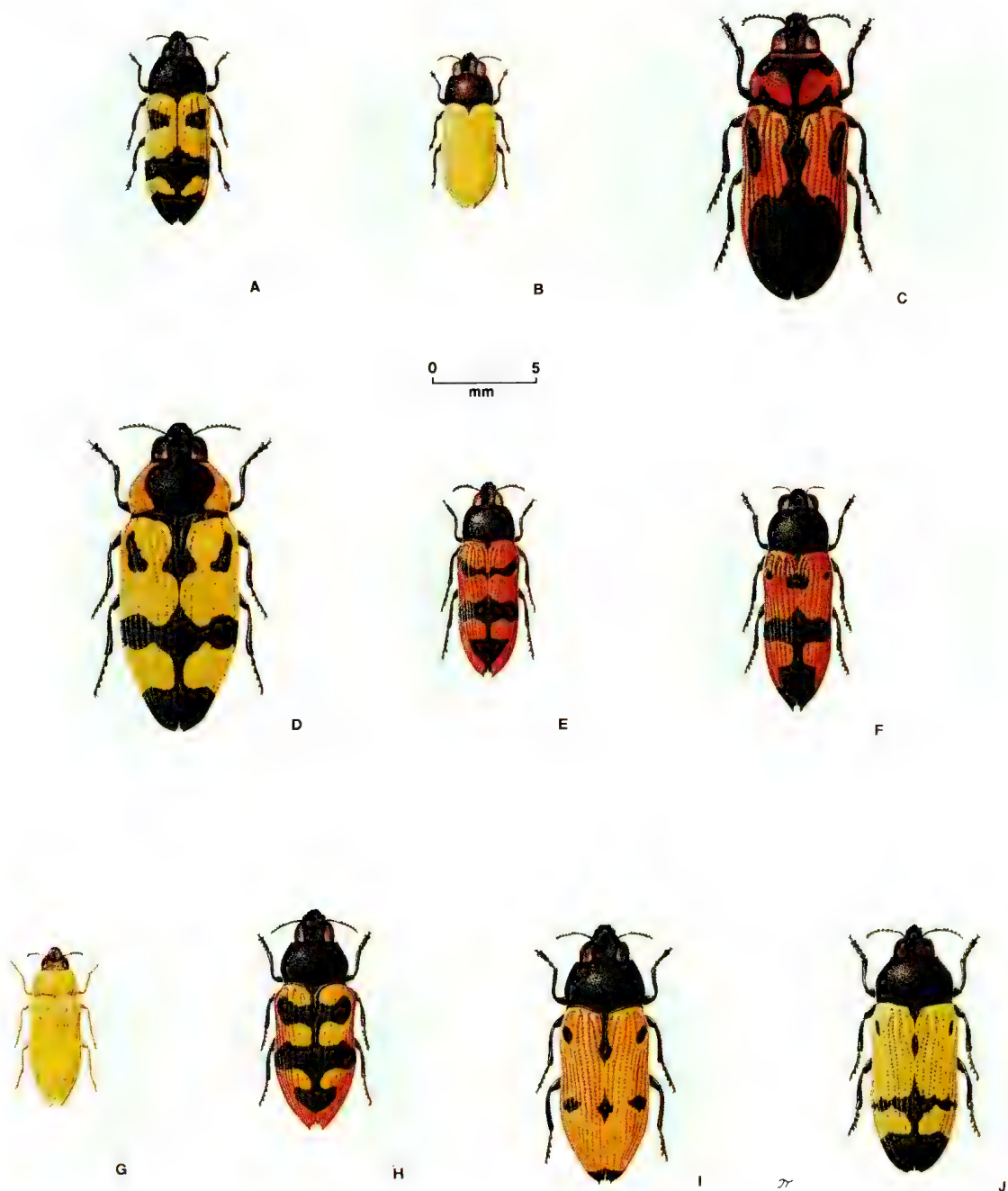


Fig. 5. A. *Stigmodera powelli* sp. nov., B. *S. dingoensis* sp. nov., C. *S. hypocrita* sp. nov., D. *S. goldingi* sp. nov., E. *S. furtiva* sp. nov., F. *S. eneabba* sp. nov., G. *S. subtestacea* sp. nov., H. *S. marginata* sp. nov., I. *S. yellowdinensis* sp. nov., J. *S. storeyi* sp. nov.

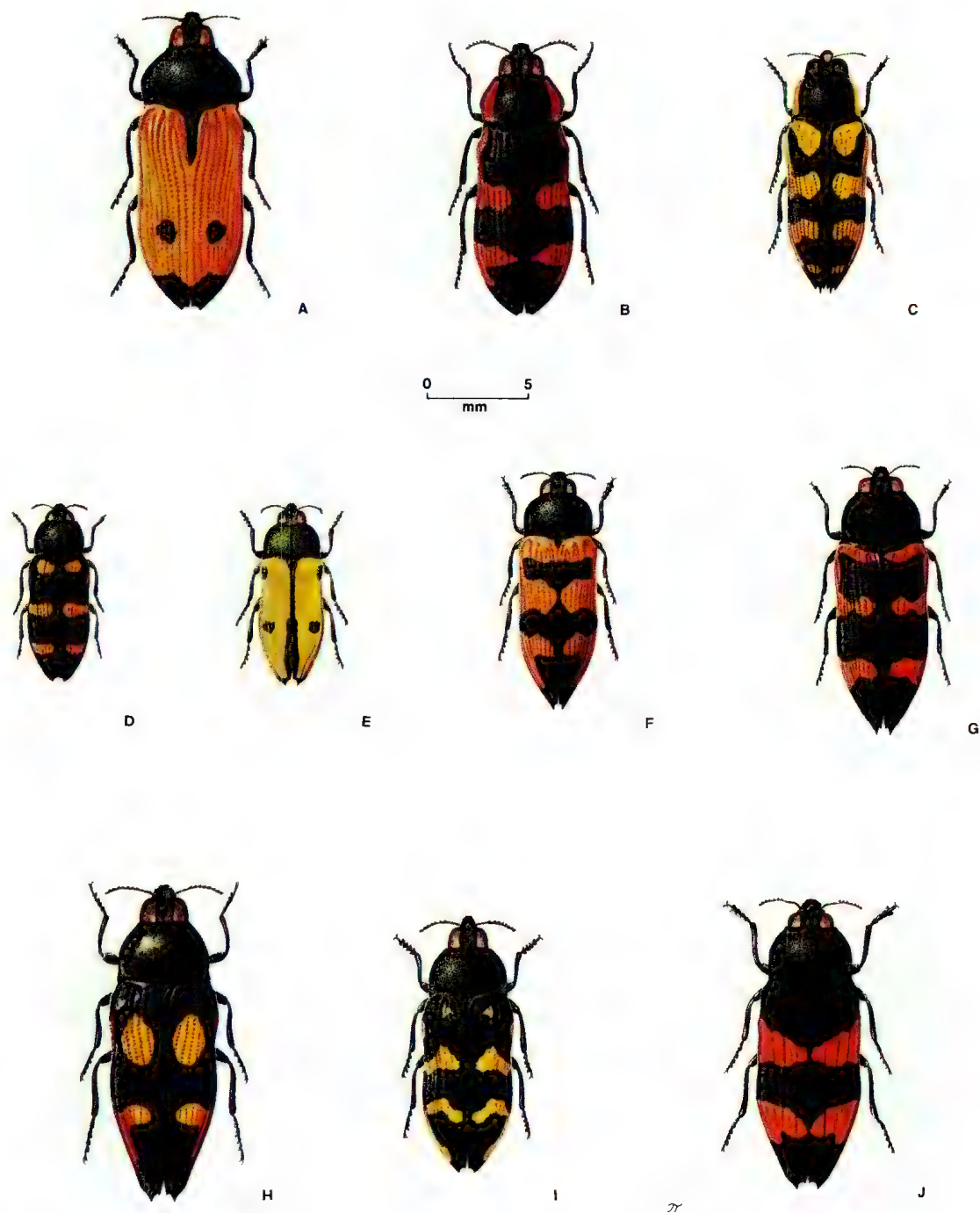


Fig. 6. A. *Stigmodera armstrongi* sp. nov., B. *S. supergrata* sp. nov., C. *S. forresti* sp. nov., D. *S. alpestris* sp. nov., E. *S. goodingi* sp. nov., F. *S. kalbarri* sp. nov., G. *S. boldensis* sp. nov., H. *S. pseudasilida* sp. nov., I. *S. dimidiata* Carter, J. *S. variegata* sp. nov.

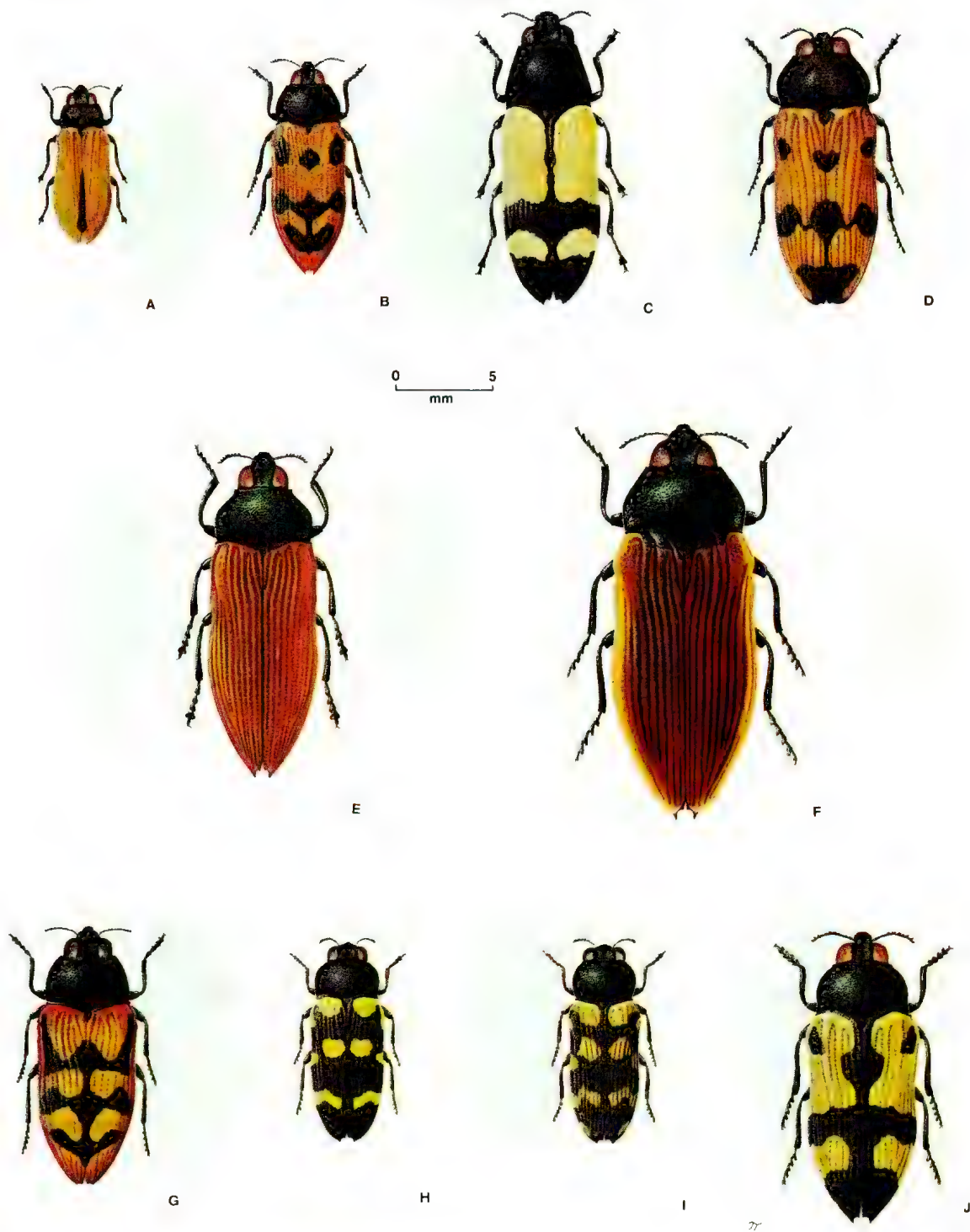


Fig. 7. A. *Stigmodera pseuderythroptera* sp. nov., B. *S. hanloni* sp. nov., C. *S. thurmerae* sp. nov., D. *S. turneri* sp. nov., E. *S. scintillata* sp. nov., F. *S. jeanae* sp. nov., G. *S. triramosa* Thomson, H. *S. chinnoeki* sp. nov., I. *S. euclae* sp. nov., J. *S. booanyia* Carter.

Paratypes. W.A.: 4 ♂, 20.x.1930, Wembley, SAMA, AMSA; ♂ & 3 ♀, same data as holotype, WAMA; 3 ♂ & ♀, 20.x.1930, Wembley. H. W. Brown, WAMA; ♀, 1.xi.1969, Wembley. E. A. Jefferys & M. Archer, WAMA; ♂, 28.x.1978, Wembley. T. M. S. Hanlon, WAMA.

Colour. Head blue-green apex, blue-black base. Antennae blue-green. Pronotum blue-black, lateral margin blue-green. Scutellum black with blue reflections. Elytra red with following black markings with blue reflections: narrow basal margin; broad pre-medial fascia concave forwards, ends not touching margin; broad post-medial fascia touching margin projecting forwards on suture; mark covering apex, all marks connected down suture. Undersurface and legs blue-green. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle very short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum closely punctured, small basal fovea extending forwards to middle as glabrous line, basal notches represented by glabrous area; projecting forwards in middle of apical margin, basal margin barely bisinuate; laterally parallel-sided at base, rounded after middle and narrowed to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals flat in middle, convex at apex, punctured and wrinkled; laterally angled out from sides, rounded at humeral callus, concave then rounded after middle to bispinose apex; marginal spines larger than sutural, inside edge of marginal spine straight, margin rounded at the base to sutural spine, apices diverging. Undersurface shallowly punctured, sparse moderately long hairs. S_7 truncate in male, bilobed in female.

Size. Males, $13.0 \pm 0.19 \times 4.7 \pm 0.09$ mm (10). Females, $13.0 \pm 0.18 \times 4.9 \pm 0.11$ mm (6).

Male genitalia. Fig. 3C. The sides of the parameres are rounded after the middle and narrowed to the apices. The median lobe is pointed at the apex and the sides acutely angled. The apophysis of the basal piece is of medium width and slightly elongated. Overall the length of the genitalia is similar to that of *S. trifasciata* (Fig. 3B) but the two are distinct.

Remarks. Belongs in the *S. trifasciata* L. & G. species group because of similarities in male genitalia and external morphology. It is the only known red and blue species in the group. The adults were collected on *Chamaechaenium* flowers. The area of capture has now been

declared as Bold Park Reserve and the specific name has been derived from this name.

Stigmodera (*Castiarina*) *pseudasilida* sp. nov.

FIG. 6H.

Holotype. ♀, Acacia Plateau, N.S.W. i.1948, H. Daylson, SAMA I 21 147.

Paratypes. 2 ♀, same data as holotype, IHQA; ♂, Cunningham Gap, Qld xii.1977, A. Hirstlett, SAMA; ♀, paratype of *S. acuta* Deuquet, RMNH; ♀, Dorrigo, N.S.W., H. J. Carter collection, NMVA.

Colour. Head, antennae, pronotum, under-surface and legs green. Scutellum green with blue reflections. Elytra basal colour yellow, margin red with following black markings: broad pre-medial fascia covering basal margin and reaching lateral margin; broad fascia at middle reaching margin and joining 1st fascia, enclosing large yellow basal spot on each elytron and small red mark on margin; elongate pre-apical mark covering apex and spines, enclosed between 2nd fascia a yellow spot which merges into a red margin. Hairs silver.

Shape and sculpture. Head with sparse shallow punctures, glabrous, median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum with sparse shallow punctures, glabrous, very small basal fovea and very small basal notches 2/3 distance from middle to margin, large fovea on each side in angles of margin; projecting forwards in middle of apical margin, basal margin bisinuate; laterally parallel-sided, rounded before middle and narrowed to apex. Scutellum scutiform, without punctures, glabrous, flat. Elytra punctate-striate, scutellary, 3rd, 5th and 9th intervals from suture convex, slightly raised and glabrous, margin flattened, intermediate intervals flat; laterally angled out from base, rounded at humeral callus, concave, then rounded after middle, tapered to bispinose apex; marginal spine larger than sutural, margin rounded and indented between, apices diverging. Undersurface with sparse shallow punctures, very sparse short hairs. Mesosternal process raised, S_7 truncate in male, rounded in female.

Size. Male, 13.2×4.8 mm (1). Females, $14.2 \pm 0.29 \times 5.2 \pm 0.07$ mm (5).

Male genitalia. Unknown, as the only male specimen available has been gutted.

Remarks. This species resembles an Asilid fly in profile as do many of the species in the "producta" mimicry complex. It occurs on the

edge of high altitude rain forest. It is not possible to place the species within a species group because male genitalia are as yet unavailable. The female paratype of *S. acuta* Deuquet is clearly unassociated with males of that species which is a synonym of *S. delicatula* Kerremans. The specific name is derived from *pseudos* Gr. false and *asillus* L. gadfly.

***Stigmopera (Castiarina) variegata* sp. nov.**

FIGS 3F, 6J.

Holotype, ♂, Corin Dam Rd., Kangaroo Creek, A.C.T. 28.ii.1972, R. J. Kohout, ANIC.

Allotype, ♀, Mt Buffalo, Vic. 29.xii.1951, F. J. Wilson, NMVA.

Paratypes, A.C.T.: ♂, Blundells, 4.ii.1935, W. Raftery, ANIC; ♂, Blundells, 26.xii.1960, M. Margules, ANIC; ♂, same data as holotype, SAMA. Vic.: ♀, Gippsland, NMVA; ♂, Beaconsfield, i.1924, NMVA; ♀, Warburton, C. Oke, NMVA; ♀, Nurbathong, 22.i.1949, F. E. Wilson, NMVA; ♀, no data, NMVA; ♀, Acheron Way, 11.i.1971, R. G. Thompson, RTVA; ♀, ZMHU.

Colour. Head green with bronze reflections. Antennae green with yellow reflections. Pronotum green with bronze reflections at margins. Scutellum green with bronze reflections. Undersurface green with yellow reflections. Legs blue-green. Elytra red with following black markings with green reflections: basal margin; broad pre-medial fascia; broad post-medial fascia; mark covering pre-apex and apex. Hairs silver.

Shape and sculpture. Head closely punctured, deep median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum closely punctured, basal fovea, basal notches on each side closer to margin than to middle, broad fovea at basal margin on each side; apical margin straight, basal margin barely bisinuate; laterally gradually rounded out from base, rounded before middle and narrowed to apex, margin near base dorso-ventrally flattened. Scutellum scutiform, punctured, excavate. Elytra costate; scutellary, 3rd, 5th, 7th and 9th intervals convex and raised and smooth, those between flat and wrinkled, lateral margins flattened; laterally angled out from base, rounded at humeral callus, then concave and rounded after middle to bispinose apex; marginal spine larger than sutural, margin rounded and indented between, apices diverging. Undersurface with small shallow punctures, moderately dense short hair. S_7 truncate in both sexes.

Size. Males, $13.2 \pm 0.35 \times 4.9 \pm 0.13$ mm (6). Females, $12.7 \pm 0.4 \times 5.0 \pm 0.17$ mm (6).

Male genitalia. Fig. 3F. Sides of parameres angled outwards rounded just before apex. Median lobe pointed in middle and angled outwards at sides. The apophysis of basal piece medium width. Very similar to the genitalia of *S. coerulescipes* Saunders (Fig. 3G) which is thicker with the apophysis of the basal piece wider.

Remarks. Belongs in *S. coerulescipes* Saunders species group because of similarities in male genitalia and external morphology. The specific name is derived from *variegatus* L., of different sorts (colours).

***Stigmopera (Castiarina) pseuderythroptera* sp. nov.**

FIGS 3H, 7A.

Holotype, ♂, Wyberba, Qld E. Sutton, QMBA.

Colour. Head black with bronze reflections. Antennae black with blue reflections. Pronotum and scutellum black with bronze reflections. Elytra red-brown with narrow black basal margin and narrow black elongate sutural mark from before middle to pre-apex. Undersurface and legs dark blue. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4 $\frac{1}{2}$ -toothed, 5-11 toothed. Pronotum closely punctured, very deep broad fovea extending to apical margin as impressed line; apical margin straight, basal margin bisinuate; laterally rounded from base to apex widest before middle; margin dorso-ventrally compressed near base. Scutellum cordiform without punctures, excavate in middle. Elytra costate, 3rd and 5th intervals from suture prominently so, scutellary, 7th and 9th less so, apical margin turned upwards, other intervals flat, heavily punctured; laterally angled out from base to humeral callus there noticeably wider than pronotum, rounded then concave, rounded widest part after middle, rounded to bispinose apex; marginal spine larger than sutural, margin rounded and slightly indented between, apices diverging slightly. Undersurface close shallow punctures, moderately haired, hairs short. S_7 truncate in male. Male tarsal pads: on legs 2 and 3, absent on tarsomeres 1, 2 and 3, replaced respectively by median triple, double, triple spines.

Size. Male, 7.9×3.0 mm (1).

Male genitalia. Fig. 3H. Sides of the parameres rounded after the middle and narrowed to the apex. Median lobe sharp and sides acutely angled. Apophysis of basal piece medium width.

Remarks. Not a member of *S. sexplagiata* Gory group as male genitalia not triangular-shaped and differs from the other lycid mimicking species. I am unable to associate this species with any other. The specific name is derived from *pseudos* Gr. false and *erythrop-tern*.

***Stigmodera (Castiarina) hantoni* sp. nov.**

FIGS 3I, 7B.

Holotype. ♂, Toolina Rockhole, Balladonia district, W.A., 3.x.1979. *T. M. S. Hanton & G. Harold*, WAMA.

Allotype. ♀, same data as holotype, WAMA.

Paratypes. 12 ♂ & 2 ♀, same data as holotype, SAMA & WAMA & MPWA.

Colour. Head, antennae, scutellum, pronotum and undersurface either green-bronze or blue-bronze. Legs: femora and tibia either bronze, dull blue or green-blue; tarsi green. Elytra testaceous in centre surrounded by intense salmon-pink with following dark blue markings: basal margin; elongate angled spot on each humeral callus; pre-medial diamond-shaped mark on suture; post-medial fascia consisting of diamond-shaped mark on suture connected to a more or less diamond-shaped mark on each elytron, not reaching margin; irregular pre-apical mark, last two connected down suture to apex. Apex and spines covered in heavily marked specimens, the spines only in lightly marked specimens. Hairs silver.

Shape and sculpture. Head closely punctured, broad median sulcus, muzzle short. Antennae: segments 1-3 obovate, 4-11 toothed. Pronotum closely punctured, basal fovea extending to middle as glabrous line; apical margin projecting forwards in middle, basal margin barely bisinuate; laterally parallel-sided at base, then rounded to widest point before middle, rounded and narrowed to apex. Scutellum scutiform, few punctures, excavate. Elytra punctate-striate, intervals flat at base, convex elsewhere, punctured on lateral margin smooth in centre; laterally angled from base, rounded at humeral callus, concave until after middle then rounded and tapered to hispinose apex; marginal spine small and blunt, sutural spine minute, margin indented and rounded between, apices slightly diverging. Under

surface closely punctured and hairy, hairs moderately long. S_7 truncate in males, narrowed and rounded in females.

Size. Males, $10.7 \pm 0.2 \times 4.0 \pm 0.1$ mm (13). Females, $12.8 \pm 0.11 \times 4.8 \pm 0.05$ mm (3).

Male genitalia. Fig. 3I. The sides of the parameres are straight after the middle and slightly angled outwards until they round off to the apex. The median lobe is sharp and the sides angled outwards. The apophysis of the basal piece is of medium width. The genitalia closely resemble those of *S. octomaculata* Saunders (Fig. 3J) which are slightly wider.

Remarks. Placed in *S. octomaculata* Saunders species group on the basis of similarities in male genitalia and external morphology. All specimens were collected at one locality on the flowers of *Eucalyptus diversifolia*. Named after Mr T. M. S. Hanton.

***Stigmodera (Castiarina) subvicina* sp. nov.**

FIGS 3K, 4B.

Holotype. ♂, Morwell, Vic. 22.xi.1958, *M. Coulson*, ANIC.

Allotype. ♀, Morwell, Vic. 20.i.1958, *Carne, Helman, Greaves*, ANIC.

Paratypes. Vic.: ♀, Traralgon, 7.i.1959, *G. T. Coulson*, SAMA; ♂, Traralgon, 7.i.1959, *G. T. Coulson*, ANIC; ♂ & ♀, Traralgon, 9.i.1959, *G. T. Coulson*, ANIC; ♂, Traralgon, 10.ii.1959, *G. T. Coulson*, ANIC; ♂, Morwell, 30.xi.1953, *M. & G. Coulson*, ANIC; ♂, Morwell, 30.xi.1958, *M. & G. Coulson*, SAMA; ♀, Morwell, 9.xii.1958, *M. & G. Coulson*, ANIC; ♂, Morwell, 20.xii.1958, *M. & G. Coulson*, ANIC; ♂, Morwell, 23.xii.1964, *G. T. Coulson*, ANIC. N.S.W.: ♂, Armidale, 14.xii.1958, *P. S. Paul*, ANIC; ♂, Grafton, 5.xii.1954, *P. S. Paul*, ANIC; ♀, 32 km N-E Rylstone, 1.xii.1951, *T. G. Campbell*, ANIC; ♂, Nowra Rd, Corang R. Crossing, 9.xii.1972, *J. Baulderson*, ANIC; ♂, Durras, 29.xi.1964, *I. Cameron*, ANIC; ♂, Queenbeyan, 18.i.1963, *S. Barker*, SAMA; ♂ & ♀, Nat. Park, xi.1952, *R.D.*, ANIC; 2 ♂ & ♀, Wahroonga, *H. J. Carter*, ANIC; ♀, Manly, E. W. Ferguson Coll., ANIC; ♀, Mitiagong, E. W. Ferguson Coll., ANIC. A.C.T.: ♀, Cotter R., 10.xii.1953, *Fuller*, ANIC; ♂ & ♀, Black Mt 14.ii.1954, *E. F. Reik*, ANIC; ♂, Black Mt 23.i.1962, *D. P. Carne*, ANIC; ♂, Tidbinbilla Nat. Res. 27-28.ii.1972, *R. J. Kohout*, ANIC; ♂, no data, ANIC.

Colour. Head, pronotum, and scutellum black with blue and/or bronze reflections. Antennae: segments 1-2 blue, 3-11 bronze. Undersurface dark purple. Legs: femora and tibia dark purple; tarsi blue. Elytra yellow with following dark blue markings: broad basal fascia reaching margin, enclosing a yellow spot on each elytron at base of lateral margin, absent in some specimens, enlarged in others; broad

fascia at middle reaching margin; broad pre-apical mark also covering apex, all marks connected down suture. Hairs silver.

Shape and sculpture. Head shallowly punctured, median sulcus, short muzzle. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum shallowly punctured, basal fovea extending forwards to middle as glabrous line, basal notches closer to margin than to middle; apical margin straight, basal margin bisinuate; laterally parallel-sided at base rounded outwards before middle, narrowed to apex. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex slightly punctured, lateral margin flat and extended outwards; laterally angled out from base, rounded at humeral callus, concave, rounded after middle and narrowed to hispinose apex; small marginal spine, smaller sutural spine, margin rounded and indented between, apices diverging. Undersurface close shallow punctures, moderately hairy, hairs short, S_7 truncate in males, rounded in females. Mesosternal process inflated.

Size. Males, $12.8 \pm 0.2 \times 5.0 \pm 0.1$ mm (20). Females, $13.3 \pm 0.3 \times 5.4 \pm 0.1$ mm (11).

Male genitalia. Fig. 3K. The sides of the parameres bulge outwards in the middle and again just before they round off to the apex. The median lobe has a long sharp point and the apophysis of the basal piece is of medium width. The shape of the male genitalia of this species place it in the *S. vicina* Saunders species group. The genitalia are close to *S. distincta* Saunders (Fig. 3L) but the median lobe in that species has a slightly thicker spine and the apophysis of the basal piece is thinner.

Remarks. This species has been confused with *S. vicina* Saunders. The apices differ as in *S. vicina* the spines are widely separated and there is a straight interval between. In *S. subvicina* the margin is indented between the spines. The specific name is derived from *sub* L. under, *vicina*.

Stigmodera (Castiarina) *scintillata* sp. nov.

FIGS 3M, 7E.

Holotype. ♂, Stanthorpe, Qld, xii.1968, J. Harslett, SAMA 1 21 148.

Allotype. ♀, Pyramids, Qld, 13.xii.1944, E. Sutton, SAMA 1 21 149.

Paratypes. ♂, Stanthorpe, Qld, xii.1954, J. Gemmell, ANIC; 6 ♂ & 4 ♀, Pyramids, Wyberba, Qld, 12/13.xii.1944, 17/18.xii.1948, 25.xii.1956, E. Sutton, QMBA, SAMA, EAQA; ♀, no data, ANIC.

Colour. Head, antennae, pronotum, scutellum, undersurface and legs bright green with yellow reflections. Elytra yellow with narrow dark green basal margin and narrow dark green strip along suture except near scutellum, spines black. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum closely punctured, glabrous; basal fovea and basal notches on each side, closer to margin than to middle; projecting forwards strongly in middle of apical margin, basal margin barely bisinuate; laterally parallel-sided at base, rounded out before middle, rounded and narrowed to apex, dorso-ventrally flattened at base. Scutellum cordiform, punctured, glabrous, excavate. Elytra punctate-striate, intervals convex, more so at apex than base, small punctures, slightly wrinkled; laterally parallel-sided at base, then slightly angled outwards, rounded at humeral callus, concave until after middle, rounded and narrowed to hispinose apex; marginal spine larger than sutural, margin rounded and indented between apices barely diverging. Undersurface with close shallow punctures. Hairs short and sparse. S_7 rounded in both sexes.

Size. Males, $17.0 \pm 0.26 \times 6.1 \pm 0.12$ mm (8). Females, $19.5 \pm 0.4 \times 7.1 \pm 0.01$ mm (5).

Male genitalia. Fig. 3M. The sides of the parameres are angled outwards for most of their length but are parallel just before they round off to the apex. The median lobe is pointed and the sides are angled outwards. The apophysis of the basal piece is wide. Male genitalia of *S. variopicta* Thomson (Fig. 3N) are very similar except that the apophysis of the basal piece is not as wide.

Remarks. Close to *S. variopicta* Thomson but differs in colour and male genitalia. The specific name is derived from *scintillatus* L. glitter.

Stigmodera (Castiarina) *jeanae* sp. nov.

FIGS 3P, 7F.

Holotype. ♂, Wyberba, Qld 11.xi.1939, J. Sutton, QMBA.

Allotype. ♀, Stanthorpe, Qld, P.H., ANIC

Paratypes. ♂, Stanthorpe, Qld 11.xi.1936, QMBA; ♀, Wyberba, Qld 29.xii.1939, E. Sutton, QMBA; ♂, Wyberba, Qld 29.xii.1950, E. Sutton, J. Gachet, SAMA; ♀, Stanthorpe, Qld vi.1958, J. Gemmell, ANIC; ♀, Stanthorpe, Qld, E. Sutton,

ANIC 2, Emerald, Vic. xi.1905, *Jurvis*, SAMA;
 ♀ Corin Dam Rd, Kangaroo Crk, A.C.T. 28.ii.
 1972, R. J. Kohout, ANIC.

Colour. Head, antennae, pronotum, scutellum, undersurface and legs bright metallic green. Elytra reddish-brown with narrow dark green basal margin, backed with black from scutellum to level with marginal notches on scutellum, lateral margin yellow on two outer intervals. In some specimens, intervals in middle yellow at basal ends merging into red-brown at apical ends. Apical spines dark green. Hairs silver.

Shape and sculpture. Head punctured, deep median sulcus, muzzle short. Antennae: segments 1-3 obconic, 4-11 toothed. Pronotum shallowly punctured, median glabrous line from base to apex in some specimens, to middle only in others, with glabrous area on each side in middle towards apex and another on each side near basal angle in some specimens, basal notch on each side closer to margin than to middle; apical margin projecting in middle, basal margin bisinuate; laterally angled outwards from base, angled before middle, narrowed to apex, lateral margins dorso-ventrally flattened near base forming a ledge enclosing two ill defined fovea in the angles. Scutellum scutiform, punctured, flat. Elytra punctate-striate, intervals convex and smooth, lightly punctured; laterally angled out from base, rounded at humeral callus, concave until after middle, rounded to bispinose apex; marginal spine long and conical, sutural spine short, margin rounded and indented between, apices diverging. Undersurface with shallow punctures, moderately long sparse hair, S_7 truncate in male, rounded and slightly pointed in female. Tarsal claws in males broader and more angled than in females.

Size. Males, $20.7 \pm 0.59 \times 8.0 \pm 0.45$ mm (31). Females, $21.8 \pm 0.56 \times 8.2 \pm 0.27$ mm (6).

Male genitalia. Fig. 3P. The sides of the parameres bulge outwards after the middle and become parallel-sided towards the apices where they round off abruptly. The median lobe is bluntly pointed in the middle, the sides are angled away and then form a ledge before they drop off vertically. In *S. semicincta* L. & G. (Fig. 3O) the sides of the parameres are angled outwards and are not as abruptly rounded to the apices. The median lobe is bluntly pointed but the sides are angled away

until they drop off vertically. The apophysis of the basal piece in both species is wide.

Remarks. Belongs to *S. semicincta* L. & G. species group because of similarities in male genitalia and external morphology. Stanthorpe specimens are bright green, the single specimen from A.C.T. dull green with blue-green undersurface. *S. semicincta* has black elytra with yellow lateral margins and the rest of the body is dark blue, whereas *S. jeanae* has pale brown elytra with yellow margins and a green body. Named after Mrs. J. Harslett, Amiens, Qld.

Stigmodera (Castiarina) *triramosa* Thomson
 1879

FIGS 3Q, 7G.

Stigmodera triramosa Thomson 1879: p. 32. Kerremans, 1892: p. 158. 1902: p. 214.

Holotype. ♂, Adelaide, S. Aust. MNHN.

Colour. Head, antennae, pronotum, undersurface and legs olive green with bronze reflections. Scutellum blue-green with bronze reflections. Elytra yellow with red margins and with following black markings with blue or blue-green reflections: narrow basal margin; narrow pre-medial fascia not reaching margin connected at the end to a vitta running obliquely to the humeral callus, projecting forwards at suture; narrow post-medial anchor shaped mark, all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, narrow median sulcus, eyes bulbous, muzzle short. Antennae compressed; segments 1-4 obconic, 5-11 toothed. Pronotum closely punctured, small basal fovea extending to apical margin as glabrous line; apical margin projecting in middle, basal margin almost straight; laterally parallel-sided at base, rounded before middle then tapered to apex. Scutellum without punctures, glabrous, excavate. Elytra punctate-striate, intervals convex more so at apex and sides than in middle, deeply punctured; laterally parallel-sided at base angled out then rounded at humeral callus, concave then rounded after middle, rounded to bispinose apex; spines small and equal, margin rounded between. Undersurface with shallow punctures, densely haired, hairs long. S_7 truncate in both sexes. **Size.** Males, $12.7 \pm 0.17 \times 5.0 \pm 0.08$ mm (20). Females, $12.9 \pm 0.47 \times 5.1 \pm 0.23$ mm (11).

Distribution. S. Aust.: Lucindale, Kangaroo Isd, Eyre Peninsula, Vic.: Little Desert, Casterton.

Male genitalia. Fig. 3Q. The parameres are parallel-sided after the middle and are rounded off abruptly to the apices. The median lobe is pointed and narrow and the apophysis of the basal piece is narrow. In *S. simulata* L. & G. (Fig. 3R) the sides of the parameres are angled outwards after the middle then gently rounded off to a narrow apex. The median lobe is also pointed and narrow but the apophysis of the basal piece is wide.

Remarks. Member of *S. simulata* L. & G. species group. *S. triramosa* has yellow elytra with green markings and red margin and the rest of the body is green. *S. simulata* has yellow elytra with black markings and the rest of the body is bronze.

Stigmodera (Castiarina) chinnocki sp. nov.

FIGS 3S, 7H.

Holotype. ♂, 9.1 km S Lake Varley T.O., Hyden-Southern Cross Rd. W.A. 6.xii.1980, R. J. Chinnock, WAMA.

Allotype. ♀, same data as holotype, WAMA.

Paratypes. W.A.: ♂, same data as holotype, SAMA; ♀, 1.6 km W N-W Balladonia Motel, 3.xi.1969, K. Kev & M. Upton, ANIC; 2 ♂ & 5 ♀, 18-32 km W Balladonia, 17.x.1982, S. Barker, P. G. Kempster & H. Vanderwoude, WAMA & SAMA; ♀, 18 km S-W Deralinya Ruin, Balladonia district, 22.x.1982, S. Barker, P. G. Kempster & H. Vanderwoude, SAMA.

Colour. Head, antennae, undersurface and legs bronze. Pronotum bronze with purple reflections. Scutellum dark blue with purple reflections. Elytra yellow with following black markings: narrow basal margin; pre-medial fascia expanded at both ends, anteriorly touching basal margin, posteriorly touching lateral margin, enclosing a yellow spot in middle at base and at humeral callus on margin; post-medial fascia reaching margin, projecting obliquely forwards from middle and touching margin enclosing yellow spot in middle between 1st and 2nd fascia and spot on margin between oblique projection and 2nd fascia; mark covering whole apex, all marks connected down suture. Hairs silver.

Shape and sculpture. Head closely punctured, small median sulcus, muzzle very short. Antennae compressed; segments 1-4 obconic, 5-11 toothed. Pronotum closely punctured; basal foveae extending to middle as glabrous line, basal notches obscure; apical margin straight,

basal margin bisinuate; laterally rounded from base to apex widest before middle. Scutellum cordiform, without punctures, excavate at anterior margin. Elytra punctate-striate, intervals convex, more so at sides and apex, heavily punctured at sides, less in middle; laterally angled out from base, rounded at humeral callus, concave, rounded after middle and narrowed to hispinose apex; spines small, margin rounded and indented between, apices diverging, apical margin sub-serrate including interval between spines. Undersurface with shallow punctures, moderately hairy, hairs moderately long. S_7 rounded in both sexes.

Size. Males, $9.2 \pm 0.35 \times 3.5 \pm 0.14$ mm (4). Females, $10.8 \pm 0.09 \times 4.0 \pm 0.06$ mm (8).

Male genitalia. Fig. 3S. The sides of the parameres are rounded outwards well before the middle and rounded off and narrowed to the apices. The median lobe is pointed and the sides angled acutely outwards. The apophysis of the basal piece is elongate and medium width. The aedeagus of *S. cupricauda* Saunders (Fig. 3T) is slightly larger. The sides of the parameres are rounded outwards gradually and are more abruptly rounded to the apex. The median lobe is blunter at the apex and the apophysis of the basal piece is slightly more elongate and of medium width.

Remarks. Closest species on basis of external morphology and male genitalia is *S. cupricauda* Saunders which occurs in N.S.W. and is a more elongate species. Three 1980 specimens were collected on *Eremophila inflata* an endangered plant. Balladonia specimens were collected on the flowers of *Eremophila pauciflora*, *E. lanantha* & *E. scoparia*. Named after Mr R. J. Chinnock, South Australian Herbarium.

Stigmodera (Castiarina) turneri sp. nov.

FIGS 3U, 7D.

Holotype. ♂, 10 km W Euabalong West, N.S.W. 18.xi.1981, J. R. Turner, SAMA 1 21 150.

Allotype. ♀, 10 km W Euabalong West, N.S.W. 19.xi.1981, J. R. Turner, SAMA 1 21 151.

Paratypes. 2 ♂, 10 km W Euabalong West, N.S.W. 28.xi.1981, J. R. Turner, JINA; 9 ♂ & 5 ♀, 22-27 km E Kimba, S. Aust. 25.x.1982, S. Barker, P. G. Kempster & H. Vanderwoude, SAMA.

Colour. Head bronze with coppery reflections at base. Antennae, undersurface and legs bronze. Pronotum bronze with or without

coppery reflections. Elytra pale yellow with following markings: narrow dark brown basal margin; black pre-medial fascia not reaching margins and expanded anteriorly and posteriorly at ends, represented in most specimens by a spot towards the margin on each elytron and one on suture; black post-medial fascia reaching margin, consisting of an elongate angled spot on each elytron and one on suture, all connected by a thin band on each side; black spade-shaped mark covering apex. Hairs silver.

Shape and sculpture. Head with close punctures, broad median suture, prominent ridge inside each antennal cavity, very short muzzle, eyes bulbous. Antennae compressed: segments 1-3 obconic, 4-11 toothed. Pronotum with large punctures, basal fovea extending forwards as impressed line to near apical margin, basal notches represented by glabrous area on each side closer to margin than middle; projecting forwards slightly in middle of apical margin, basal margin barely bisinuate; laterally parallel-sided at base, rounded to widest part before middle, rounded to apex. Scutellum scutiform, without punctures, excavate. Elytra punctate-striate, convex with heavy punctures; laterally parallel-sided at base, angled outwards, rounded at humeral callus, concave, rounded after middle and narrowed to truncate apex, no marginal spine, minute sutural spine, apices slightly diverging, apex sub-serrate. Undersurface with shallow punctures, edges of abdominal sclerites without punctures, glabrous. Sparse short hairs. S_7 truncate in males, rounded and slightly pointed in females. **Size.** Males, $13.9 \pm 0.19 \times 5.3 \pm 0.06$ mm (12). Females, $15.1 \pm 0.4 \times 5.8 \pm 0.18$ mm (6).

Male genitalia. Fig. 3U. The parameres are parallel-sided after the middle and round off abruptly to the apices. The median lobe is broad and bluntly pointed and the sides angled outwards. The apophysis of the basal piece is wide. In *S. convexa* Carter (Fig. 3W) the parameres are parallel-sided towards the apices and round off abruptly to the apices. The median lobe is bluntly pointed and the sides angled outwards. The apophysis of the basal piece is medium width.

Remarks. This species is closest to *S. convexa* Carter. It is larger and has yellow elytra while those of *S. convexa* are red. It has been found associated with *Myoporum arctatum* and *Eremophila longifolia* in N.S.W. and with

Eremophila scoparia in South Australia. Named after Mr J. R. Turner, Hill End, N.S.W.

Stigmodera (Castiarina) *euciae* sp. nov.

FIGS 3V, 7I

Holotype. ♂, 36 km E S.A./W.A. border, 27.xii.1980, M. Golding & M. Powell. SAMA I 21 152.

Allotype. ♀, 35 km E S.A./W.A. border, *Eremophila weldii*, 21.xi.1982, J. M., S., & S. J. Barker, SAMA I 21 153.

Paratypes. 4 ♂, same data as holotype, MPWA: 3 ♂ & 6 ♀, same data as allotype, SAMA.

Colour. Head, antennae, pronotum, under-surface and legs bronze. Scutellum bronze with purple reflections. Elytra yellow with following bronze markings: narrow basal margin; pre-medial fascia expanded at each end anteriorly over humeral callus and posteriorly touching margin and enclosing yellow spot; post-medial fascia touching margin expanded forwards obliquely in middle of anterior edge, touching 1st fascia and enclosing large yellow spot in middle and smaller one on margin; pre-apical spade-shaped mark which expands laterally enclosing a spot on apical margin, all marks connected down suture. Markings much heavier in some specimens and in these there are 7 yellow spots, 4 on the margin and 3 in the middle. Hairs silver.

Shape and sculpture. Head with close deep punctures, median suture, muzzle very short, eyes bulbous. Antennae compressed: segments 1-4 obconic, 5-11 toothed. Pronotum with close deep punctures, hairy at lateral edges; elongate basal fovea extending to middle as glabrous line, basal notches obscure; projecting forwards in middle of apical margin, basal margin almost straight; laterally rounded from base to apex, widest in middle. Scutellum cordiform, excavate, glabrous. Elytra punctate-striate, striae deep near apex, intervals convex with deep punctures; laterally angled outwards from base rounded at humeral callus, concave, rounded after middle and narrowed to hispinose apex; marginal spine larger than sutural, margin indented between, apices diverging slightly. Undersurface: with shallow punctures, edges of abdominal sclerites glabrous; hairy, hairs moderately long. S_7 truncate in both sexes.

Size. Males, $10.6 \pm 0.18 \times 3.8 \pm 0.09$ mm (8). Females, $11.6 \pm 0.16 \times 4.3 \pm 0.08$ mm (7).

Male genitalia. Fig. 3V. The parameres are parallel-sided after the middle and round off abruptly to the apices. The median lobe is sharp and the sides are curved away at an angle. The apophysis of the basal piece is very narrow. *S. cupricauda* (Fig. 3T) has a blunt median lobe and the apophysis of the basal piece is wider.

Remarks. Grouped with *S. cupricauda* Saunders on the basis of male genitalia and external morphology. Distinguished by being a broader species and differences in male genitalia. All specimens examined were collected on the flowers of *Eremophila weldii*. The specific name is derived from the name of the district where it was collected.

Stigmodera (*Castiarina*) *booyania* Carter 1933

FIG. 7J.

Stigmodera booyania Carter, 1933: p. 162. Barker & Edward, 1963: p. 170. Barker, 1979: p. 15.

Stigmodera booyania Carter, 1933: p. 162. Oberberger, 1934: p. 687.

This species was described from a unique female specimen collected by Mrs Crocker nee Baesjou on 20.xi.1931 on *Myoporum platycarpum* R. Br. at Booyania Stn, Norseman district, W.A. The type is located in the NMVA. With P. G. Kempster on 20.xi.1980 I collected a series on flowers of *M. platycarpum* on Balladonia Stn W.A., now lodged in the SAMA & WAMA collections. The beetles were common and occurred with *S. subacuticeps* Barker and *S. erythroptera* (Boisduval), this is the first record of the latter species from W.A.

Acknowledgements

I wish to thank the following people for assistance: Dr G. F. Gross and Dr E. G. Matthews, South Australian Museum; Dr J. Lawrence and Mr T. Weir, Division of Entomology, C.S.I.R.O.; Dr G. B. Monteith, Queensland Museum; Ms M. Schneider and

Mr G. Daniels, Department of Entomology, University of Queensland; Dr T. F. Houston, Western Australian Museum; Miss C. M. H. von Hayek, British Museum (Natural History), London; Dr M. Uhlig, Museum of Natural Science, Humboldt University, Berlin; Dr R. Damoiseau, Institut Royal des Sciences Naturelles de Belgique, Brussels; Mr K. T. Richards, Department of Agriculture, South Perth; Mr R. I. Storey and Dr N. Gough, Department of Primary Industry, Mareeba; Dr J. Green and Dr A. S. George, Western Australian State Herbarium, South Perth; Mr R. Chinnock, South Australian Herbarium, Adelaide; Mr E. E. Adams, Edungalba; Mr G. Anderson, Cowell; Mr and Mrs R. W. Anderson, Rocky Glen; Mr and Mrs K. Carnaby, Wilga; Mrs A. E. Crocker and family, Balladonia; Mr M. Golding, Sydney; Mr T. M. S. Hanlon, Sydney; Mrs J. Harslett, Amiens; Mr K. Hateley, Kiata; Mr M. Powell, Attadale; Mr R. P. McMillan, Cottesloe; Mr and Mrs K. Schwartz, Binnaway; Mr R. G. Thompson, Ellwood; Mr J. R. Turner, Hill End; Mr G. Williams, Lansdowne; Mr A. Walford Huggins, Mt Molloy; Miss H. Vanderwoude, Mrs J. Gardner, Mr P. Kempster and Mr D. J. Williams, Department of Zoology, University of Adelaide; Ms J. Thurmer, Underdale; National Parks Board of Western Australia for permission to collect in Flora Reserves; Mr B. K. Bowen, Director, Fisheries and Wildlife Department, Western Australia for a scientific permit to collect Buprestids; The Director, National Parks and Wildlife Service, South Australia for permission to collect in National Parks; The Director, National Parks and Wildlife Service of New South Wales for permission to collect in the Warrumbungles National Park; The Research and Publications Committee, University of Adelaide for grants-in-aid of research; A.R.G.S. & A.B.R.S. for grants-in-aid of research. Mark Mitchell Trust Fund for publication costs of the coloured illustrations.

References

- BARKER, S. (1979) New species and a catalogue of *Stigmodera* (*Castiarina*) (Coleoptera: Buprestidae). *Trans. R. Soc. S. Aust.* 103, 1-23.
 — (1980) New species and synonyms of *Stigmodera* (*Castiarina*) (Coleoptera: Buprestidae). *Ibid.* 104, 1-7.
 — & EDWARD, D. H. (1963) Corrections to type localities of three species of Western Australian *Stigmodera* (Buprestidae, Coleoptera). *W.A. Nat.* 8, 169-171.
 BLACKBURN, I. (1982) Coleoptera, in Scientific results of the Elder Expedition. *Trans. R. Soc. S. Aust.* 106, 16-61.
 BOISDUVAL, J. A. (1835) *Voyage de l'Astrolabe*. (Librairie Encyclopedique de Roret; Paris.)
 CARTER, H. J. (1916) Revision of the genus *Stigmodera*, and descriptions of some new species of Buprestidae (Order Coleoptera). *Trans. R. Soc. S. Aust.* 40, 78-144.

- (1919) Notes on Australian coleoptera, with descriptions of new species. *Proc. Linn. Soc. N.S.W.* **44**, 137-173.
- (1924) Australian Coleoptera: Notes and new species. No. iv. *Ibid.* **49**, 521-544.
- (1927) Australian Coleoptera: Notes and new species. No. v. *Ibid.* **52**, 222-234.
- (1929) A check list of the Australian Buprestidae. *Aust. Zool.* **5**, 265-304.
- (1931) Notes on the genus *Stigmodera* (Family Buprestidae). Together with descriptions of new species of and a retabulation of the subgenus *Castiarina*. *Ibid.* **6**, 337-367.
- (1933) Australian Coleoptera. Notes and new species. No. VIII. *Proc. Linn. Soc. N.S.W.* **58**, 159-180.
- (1934) Australian and New Guinea Coleoptera. Notes and new species. No. III. *Ibid.* **59**, 252-269.
- (1940) Australian Buprestidae and the Junk catalogue. *Ann. Mag. Nat. Hist.* ser. **11**, No. 6, 380-389.
- DEUQUET, C. M. (1956) Notes on Australian Buprestidae, with descriptions of three new species and two sub-species of the genus *Stigmodera*, subgenus *Castiarina*. *Proc. Linn. Soc. N.S.W.* **81**, 153-156.
- DONOVAN, E. (1805) An epitome of the Natural History of the Insects of New Holland, New Zealand, Otaheite, and other islands in the Indian, Southern, and Pacific Oceans; etc. (The author and F. C. & J. Rivington: London.)
- GORY, H. (1841) Histoire Naturelle et iconographie des Insectes. Coleopteres. (Tome. iv. P. Dumenil: Paris.)
- HOPKINS, F. W. (1846) XXX. Descriptions of various new species of Buprestidae from Australia. *Trans. ent. Soc. Lond.* **4**, 208-220.
- KERREMANS, C. (1892) Catalogue synonymique des Buprestides decrits de 1758 A 1890. *Mém. Soc. r. ent. Belg.* **1**, 1-304.
- (1898) Buprestides nouveaux de l'Australie et des regions voisines. *Ann. Soc. ent. Belg.* **42**, 113-182.
- (1902) Coleoptera Serricornia Fam. Buprestidae. *Genera Insect.* **12**, 1-338 (P. Wylsman: Brussels).
- LAPORTE, F. L. & GORY, H. (1837) Histoire Naturelle et Iconographie des Insectes. Coleopteres, Tome ii. Suite aux Buprestides. (P. Dumenil: Paris.)
- MACLEAY, W. (1863) Descriptions of twenty new species of Buprestidae, belonging to the genus *Stigmodera*, from the northern parts of Australia. *Trans. ent. Soc. N.S.W.* **1**, 22-32.
- OBENBERGER, J. (1928) Opuscula Buprestologica I. *Archiv. Naturgesch.* 1926, 1-350.
- (1933) Notes on the Australian genus *Stigmodera* Eschsch. (Col. Bupr.). *Cas. čsl. Spol. entom.* **30**, 65-76.
- (1934) Buprestidae I. in *Coleopterorum Catalogus*. Vol. xii. (Junk: Den Haag.)
- SAUNDERS, E. (1868) A revision of the Australian Buprestidae described by the Rev. F. W. Hope. *Trans. ent. Soc. Lond.* 1868, 1-67.
- (1869) Insecta Saundersiana: or characters of undescribed species in the collection of William Saunders, Esq., F.R.S., F.L.S., etc., vol. iii. Buprestidae pt. 1, 1-27. (John van Voorst: Paternoster Row, London.)
- (1871) Catalogus Buprestidarum. Synonymicus et Systematicus. (E. W. Janson: 28 Museum Street, London.)
- THOMSON, J. (1879) Typi Buprestidarum Musaci Thomsoniani. Appendix 1 a. (E. Deyrolle: Paris.)
- WATT, J. C. (1979) Abbreviations for Entomological collections. *N.Z. Zool.* **6**, 519-520.

CORRELATION OF THE UPPERMOST LATE PRECAMBRIAN SUCCESSION ACROSS THE TORRENS HINGE ZONE IN THE PORT AUGUSTA REGION OF SOUTH AUSTRALIA

BY P. S. PLUMMER

Summary

Palaeoenvironmental data are used with lithologic criteria to correlate the uppermost Late Precambrian Tent Hill Formation on the Stuart Shelf with the succession in the adjacent Adelaide Geosyncline. It is found that the Tent Hill Formation (*sensu stricto*) lies above a previously unrecognized disconformity and is equivalent to the upper portion of the Wilpena Group within the geosyncline, and not the lower portion as previously believed.

CORRELATION OF THE UPPERMOST LATE PRECAMBRIAN SUCCESSION ACROSS THE TORRENS HINGE ZONE IN THE PORT AUGUSTA REGION OF SOUTH AUSTRALIA

by P. S. PLUMMER*

Summary

PLUMMER, P. S. (1983) Correlation of the uppermost Late Precambrian Succession across the Torrens Hinge Zone in the Port Augusta region of South Australia. *Trans. R. Soc. S. Aust.* **107**(3), 171-175, 30 November, 1983.

Palaeoenvironmental data are used with lithologic criteria to correlate the uppermost Late Precambrian Tent Hill Formation on the Stuart Shelf with the succession in the adjacent Adelaide Geosyncline. It is found that the Tent Hill Formation (*sensu stricto*) lies above a previously unrecognized disconformity and is equivalent to the upper portion of the Wilpena Group within the geosyncline, and not the lower portion as previously believed.

KEY WORDS: Late Precambrian, Tent Hill Formation, Torrens Hinge Zone.

Introduction

Numerous lateral facies changes within the Adelaidean succession of South Australia make accurate stratigraphic correlation difficult. Recent analyses of lithofacies distributions and detailed mapping of areas where lithofacies intertongue have enabled useful time-significant correlations to be made in the Adelaide Geosyncline. However, correlating the basal succession with that on the Stuart Shelf to the west is further complicated by an almost com-

plete lack of outcrop in the intervening Torrens Hinge Zone (Fig. 1). The only useful information available in this zone is that from the Wilkatana Oil Bore Number 1, located some 45 km north of Port Augusta.

Within the basin numerous transgressions and regressions produced a thick sedimentary succession. On the adjacent shelf, however, deposition occurred only during times of maximum transgression, resulting in a condensed sequence frequently punctuated by disconformities. Although the stratigraphies of the two areas are now well known, several differing correlations have been made between the uppermost Precambrian sediments on the Stuart Shelf—i.e. the Tent Hill Formation (*sensu* Thomson & Johnson 1968)—and the basal succession. These include the equivalence drawn (1) with the Emeroo Quartzite of the basal Burra Group (Mawson 1947); (2) with the Brachina Subgroup of the basal Wilpena Group (Coats 1965; Thomson & Johnson 1968; Thomson *et al.* 1975; Thomson 1976); and (3) with the Pound Subgroup of the upper Wilpena Group (Segnit 1939; Miles 1954; Johns 1963). All these correlations, however, were based purely on lithostratigraphic characteristics which, as Rowlands (1973) states, are inadequate and can lead to invalid palaeogeographic reconstructions. Now, however, with the recent completion of a detailed palaeogeographic study of the Brachina Subgroup (Plummer 1978a,b), new and chronostrati-

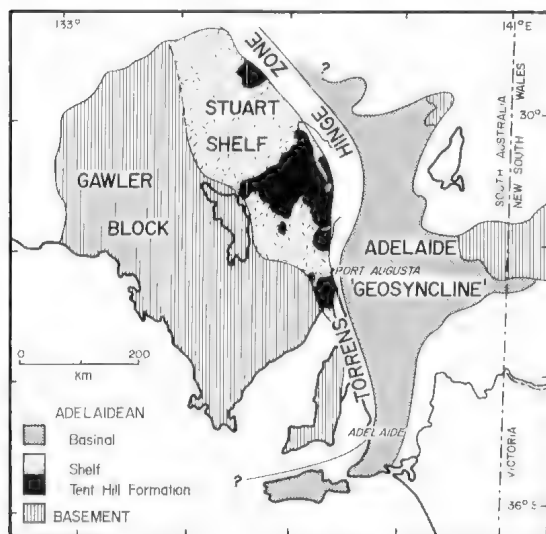


Fig. 1. Locality map showing distribution of Tent Hill Formation outcrop on Stuart Shelf.

* Department of Geology, University of Adelaide. Present address: Petroleum Development Oman, P.O. Box 81, Muscat, Sultanate of Oman.

¹ Plummer, P. S. (1978b) The upper Brachina Subgroup; a Late Precambrian intertidal deltaic and sandflat sequence in the Flinders Ranges, South Australia. Ph.D. thesis, Univ. Adel. (2 vols) (unpublished).

graphically significant criteria can be applied to the problem.

The Tent Hill Formation

Originally defined by Brown (1885) as "purple and greenish shales overlain by sandstone, quartzite and quartzose sandstone", the Tent Hill Formation has been the subject of much revision and redefinition (Table 1). Miles (1954) limited the formation (which he called the Lincoln Gap Flagstones) to the upper arenaceous sediments and defined the underlying shales as a separate formation—the Tregolana Shales. Crawford (1964) then recognized a lower red Corraberra Member and an upper white Simmens Member within the newly restricted Tent Hill Formation. Thomson (1965) showed the Tregolana Shales to be sharply divisible into a lower unit of purple shale and siltstone with green shale laminations, and an upper unit of purple shale with 10% thin beds of red sandstone. Soon after, Coats (1965) formally included these shaly units into the Tent Hill Formation as its basal member, to be in keeping with Brown's original concept. Later, Thomson & Johnson (1968) introduced yet another new member—the Whyalla Sandstone Member—and defined it as lying conformably below the Tregolana Shale Member.

Other units equivalent to members of the Tent Hill Formation on the Stuart Shelf include the Woomera Shale Member, equivalent to the Tregolana Shale Member, and the Arcoona Quartzite Member, equivalent to the Simmens Quartzite Member (Johns 1968).

Correlation of the Basal Portion of the Tent Hill Formation with the Basal Succession

Coats (1965) produced evidence which he believed supported the correlation of the Simmens Quartzite Member with the ABC Range Quartzite and the Corraberra Sandstone-Tregolana Shale Members with the Brachina Formation. These correlations were later seemingly supported when Thomson & Johnson (1968) equated their Whyalla Sandstone Member with the Seaciff Sandstone Member of the Brachina Formation—a granite-bearing sandstone believed then to replace the distinctive Nuccaleena Formation toward the margins of the basin (Thomson 1966). Lenticular dolomites, however, are present conformably below the Tregolana Shale Member in the region near the Corrapateena Arm

of Lake Torrens which Coats (*pers. comm.* 1977) maintains are typical of the Nuccaleena Formation. Further reports of the Nuccaleena Formation being present on the Stuart Shelf are to be found in Rowlands (1973) and Preiss (1979). Also, it was recently shown by Plummer (1978a) that the Nuccaleena Formation was not equivalent to the Seaciff Sandstone Member, and that the latter unit was, in fact, the uppermost member of the underlying Elatina Formation (Umberatana Group). Plummer also showed the Brachina Formation-ABC Range Quartzite stratigraphy to be more complex than previously believed, and a hitherto unrecognized unconformity at the top of the quartzite. This led to the suggestion that Coats' (1965) correlation of the Simmens Quartzite Member with the ABC Range Quartzite was incorrect, and that the equivalence he drew between the grouped Corraberra Sandstone-Tregolana Shale Members with the 'Brachina Formation' was questionable.

The massive dolomites of the Nuccaleena Formation reach a maximum thickness of about 10 m and represent deposition upon an intertidal to supratidal mudflat (Plummer 1978c). The presence of the Nuccaleena dolomites on the Stuart Shelf, and their stratigraphic position between the Whyalla Sandstone Member and Tregolana Shale Member, therefore, strongly suggest that the Whyalla Sandstone Member-Seaciff Sandstone Member correlation is correct, as explained by Horwitz (1962). Their position below the Nuccaleena dolomites, however, indicates that these members belong to the Elatina Formation and its equivalents, and not of the 'Brachina Formation' as previously thought. Also, at least the basal unit of the Tregolana Shale Member (*sensu* Thomson 1965), lying conformably above the Nuccaleena dolomites, can be confidently correlated with the Moolooloo Formation of the Brachina Subgroup, which lies conformably above the Nuccaleena Formation within the basin (see Fig. 2).

Brachina Subgroup Palaeogeography and Middle Tent Hill Formation Correlation

Although displaying a short initial transgression from the intertidal and supratidal Nuccaleena carbonate mudflat to the submerged tidal Moolooloo mudflat, the Brachina Subgroup is predominantly a regressive sequence dominated by a delta in the Port Augusta region—the ABC Range Quartzite—which steadily prograded onto a surrounding

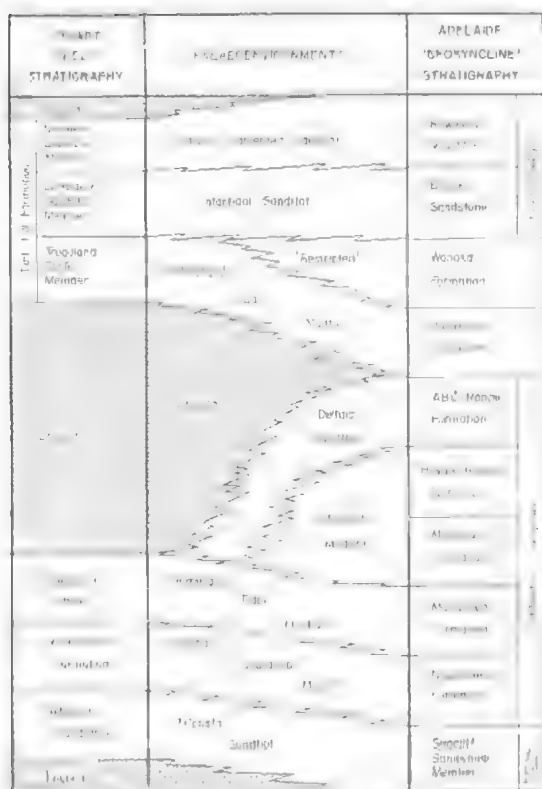


Fig. 2. Stratigraphic correlation of the Hill Formation (*sensu stricto*) with uppermost Precambrian succession in Adelaide 'Geosyncline', based on palaeoenvironmental criteria.

intertidal mudflat—the Moorillah and Bayley Range Formations. At the time of maximum regression, islands appeared in the centre of the basin and a portion of the delta complex was eroded. These reworked sediments were redeposited as an intertidal sandflat spreading meridionally along the western side of the basin. The disconformity marking this erosive phase cuts progressively deeper into the Brachina Subgroup in a westward direction (see Plummer 1978a; 1978b, Vol. 2, Fig. 7-3 & p. A4). In fact, some 650 m of sediment was removed within 2 km of the limiting eastern edge of the disconformity. Although the subgroup reaches its maximum thickness of about 2200 m in the Port Augusta region, under such severe erosive conditions, only the lowermost transgressive sediments of the subgroup (i.e. those deposited in the submerged tidal mudflat and the underlying dolomites) could be expected to be still preserved on the Stuart Shelf today. Within this region, however, out-

crop of the sandy upper members of the Tent Hill Formation occurs (see Fig. 1).

The presence of the Nuccaleena Formation on the shelf, and its conformable relationship with the overlying shales of the lower unit of the Tregolana Shale Member, indicate, therefore, that these sediments are correlative with the Nuccaleena Formation and the basal Moolooloo Formation, respectively, within the basin. However, the disconformity marking the top of the Brachina Subgroup in the marginal regions of sedimentation negates any further possibility of Tent Hill Formation-Brachina Subgroup correlation. It is interesting to note that the sharp boundary separating the two shaly units of the Tregolana Shale Member (see Thomson 1965) lies in the correct stratigraphic position to represent the disconformity on the shelf.

Upper Wilpena Group Palaeogeography and Upper Tent Hill Formation Correlation

Following the erosive climax to the Brachina Subgroup regression, a significant transgression occurred. The influx of coarse detritus into the basin had ceased, and this transgression initially produced a purple shaly tidal mudflat deposit—the Bunyeroo Formation. As this deposit steadily encroached across the Torrens Hinge Zone and onto the Stuart Shelf it was replaced by a dominantly carbonate succession—the Wonoka Formation—deposited initially under restricted, low energy conditions. Following this, coarse detritus was once again debouched into the basin. Initially a vast expanse of red crossbedded shaly sand was deposited under intertidal conditions—the Bonney Sandstone. With further transgression, a more massive, cleaner white sand was deposited within a high energy, shallow submerged environment—the Rawnley Quartzite (see Jenkins 1975).

This transgression and coarse detrital influx was recorded on the Stuart Shelf. The initial tidal mudflat encroachment produced the upper 'purple shale with 10% thin beds of red sandstone' unit of the Tregolana Shale Member. The gradation from this unit into the red shaly Corraberra Sandstone Member marks the initiation of the coarse detrital influx, whilst the further gradation from the Corraberra Sandstone Member into the white Simmens Quartzite Member records the change in deposition with transgression from an intertidal, to a shallow submerged environment. The general thinness of the Simmens Quartzite Member on the Stuart Shelf is due to later erosion, possibly

TABLE 1. Summary of historic development of Tent Hill Formation stratigraphic nomenclature.

Unit	Unit	CRAWFORD (1964)	Unit	Unit	JOHNSON (1968)	Unit
Tent Hill Formation	Angely Hill Formation	Sturt	Sturt	Sturt	Sturt	Sturt
	Tent Hill Formation	Corraberri Member	Corraberri Member	Corraberri Member	Corraberri Member	Corraberri Member
	Tregolana Shales	Tregolana Shale	Tregolana Shale	Tregolana Shale	Tregolana Shale	Tregolana Shale
					Whyalla Sandstone Member	Whyalla Sandstone Member

related to the Precambrian-Cambrian unconformity.

The presence within Wilkatana Oil Bore Number 1 of maroon and green dolomitic shales and siltstones lying disconformably beneath Cambrian deposits, and equated with the Bunyeroo and Wonoka Formations (Thomson 1969), supports the correlation of the upper Tent Hill Formation with the upper portion of the Wilpena Group. The absence of quartzite in this bore is readily explained in terms of a horst and graben basement structure to the Torrens Hinge Zone and hence erosion to a deeper stratigraphic level on the horst structure(s) prior to Cambrian deposition.

Conclusions

It is herein suggested that the sharp boundary separating the two shaly units within the Tregolana Shale Member represents the disconformity marginally present within the basin at the top of the ABC Range Quartzite. As such, a relatively large lacuna exists within the Tent Hill Formation as presently defined. To be in keeping with the Australian Code of

Stratigraphic Nomenclature (1973), it is therefore deemed necessary that the term 'Tent Hill Formation' be redefined to the restricted sequence comprising the upper shaly unit of the Tregolana Shale Member (for which this name should be retained), the Corraberri Sandstone Member and the Simmens Quartzite Member. Consequently, the lower shaly unit of the Tregolana Shale Member (referred to as the 'unnamed shale' in Table 1 and on Fig. 2), the Nuccaleena dolomite equivalents and the Whyalla Sandstone Member should all be dissociated from the Tent Hill Formation and redefined separately. This revised stratigraphic nomenclature for the uppermost Precambrian sediments on the Stuart Shelf is presented in Table 1. Figure 2 presents the correlation of this stratigraphy with the basinal succession, based on the palaeoenvironmental criteria outlined above.

Acknowledgments

Drs V. A. Gostin, R. J. F. Jenkins and B. Daily are thanked for their comments and critical reading of the manuscript.

References

- AUSTRALIAN CODE OF STRATIGRAPHIC NOMINCLATURE (1973) *J. geol. Soc. Aust.*, **20**, 105-112.
- BROWN, H. Y. L. (1885) Report on geological character of country passed over from Port Augusta to Eucla, *Parl. Paper, S. Aust.*, **45**.
- COATS, R. P. (1965) Tent Hill Formation correlations—Port Augusta and Lake Torrens, *Quart. geol. Notes, geol. Surv. S. Aust.*, **16**, 9-11.
- CRAWFORD, A. R. (1964) CULTANA map sheet, Geological Atlas of South Australia, 1:63 360 series. (Geol. Surv. S. Aust.: Adelaide.)

- HORWITZ, R. C. (1962) Some features of the lower part of the Marinoan Series of the Adelaide System. *Aust. J. Sci.* **24**, 355-356.
- JENKINS, R. J. F. (1975) An environmental study of the rocks containing the Ediacara assemblage in the Flinders Ranges. *Abstr. 1st Aust. geol. Conv., geol. Soc. Aust.*, 21-22.
- JOHNS, R. K. (1963) Stratigraphic correlations in the Lake Torrens region. *Quart. geol. Notes, geol. Surv. S. Aust.* **6**, 7-8.
- (1968) Geology and mineral resources of the Andamooka-Torrens area. *Bull. geol. Surv. S. Aust.* **41**.
- MAWSON, D. (1947) The Adelaide Series as developed along the western margin of the Flinders Ranges. *Trans. R. Soc. S. Aust.* **71**, 259-280.
- MILES, K. R. (1954) The geology and iron ore resources of the Middleback Range area. *Bull. geol. Surv. S. Aust.* **33**.
- PLUMMER, P. S. (1978a) The stratigraphy of the lower Wilpena Group (Late Precambrian), Flinders Ranges, South Australia. *Trans. R. Soc. S. Aust.* **102**, 25-38.
- (1978c) Note on the palaeoenvironmental significance of the Nuccaleena Formation (Late Precambrian), central Flinders Ranges, South Australia. *J. geol. Soc. Aust.* **25**, 395-402.
- PREISS, W. V. (1979) Adelaidean sedimentation: The Adelaide Geosyncline and Stuart Shelf. *Rep. Dept Mines Energy, S. Aust.* 79/24.
- ROWLANDS, N. J. (1973) The Adelaidean System of South Australia: A review of its sedimentation, tectonics and copper occurrences. *Proc. Belt Symposium* **1**, 80-113.
- SEGNIT, R. W. (1939) The Pre-Cambrian-Cambrian succession: The general and economic geology of these systems in portions of South Australia. *Bull. geol. Surv. S. Aust.* **18**.
- THOMSON, B. P. (1965) Erosional features of the Tent Hill Formation. *Quart. geol. Notes, geol. Surv. S. Aust.* **13**, 4-5.
- (1966) Stratigraphic relationships between sediments of Marinoan age—Adelaide region. *Ibid.* **20**, 7-9.
- (1969) Precambrian Basement Cover: The Adelaide System. In: Parkin, L. W. (Ed.): "Handbook of South Australian Geology." pp. 49-83 (Geol. Surv. S. Aust.: Adelaide).
- (1976) Precambrian geology and tectonics of the Stuart Shelf and Torrens Hinge Zone. *Excursion Guide, 25th Int. geol. Congr.* 33A: 1-11.
- , FORBES, B. G. & COATS, R. P. (1975) Adelaide Geosyncline and Stuart Shelf, S.A.—Geology. In: Knight, C. L. (Ed.): Economic geology of Australia and Papua New Guinea. Part 1: Metals. *Aust. Inst. Min. Metal., Monogr. Series* **5**, 537-542.
- & JOHNSON, J. E. (1968) Marinoan stratigraphy, Port Augusta region. *Quart. geol. Notes, geol. Surv. S. Aust.* **25**, 4-7.

HALLOYSITE IN A WEATHERED PROFILE AT PORT MACQUARIE, NEW SOUTH WALES

BY E. SLANSKY

Summary

Along the beaches at Port Macquarie on the northern coast of New South Wales outcrops a suite of ophiolitic rocks which are highly altered. At places, soft argillaceous rocks occur which consist predominantly of clay materials.

HALLOYSITE IN A WEATHERED PROFILE AT PORT MACQUARIE, NEW SOUTH WALES

by E. SLANSKY*

Summary

SLANSKY, E. (1983) Halloysite in a weathered profile at Port Macquarie, New South Wales. *Trans. R. Soc. S. Aust.* **107**(3), 177-185, 30 November, 1983.

Along the beaches at Port Macquarie on the northern coast of New South Wales outcrops a suite of ophiolitic rocks which are highly altered. At places, soft argillaceous rocks occur which consist predominantly of clay minerals.

Above Rocky Beach, halloysite occurs in a prominent horizon of blue clay, about 2 m thick, which is part of a deeply weathered profile. The profile is situated above serpentinite. Four clay mineral assemblages were recognized in the profile from the bottom to the top: (i) mainly smectite with some illite and a serpentine mineral, (ii) halloysite, (iii) kaolinite, and (iv) kaolinite and illite. Halloysite tubes, as seen under SEM, are of two types: well developed with an aspect ratio $>10:1$, and (ii) arranged in a dense aggregate with an aspect ratio $<10:1$. The halloysite was shown to be originally the 10 \AA form, but during storage and handling, partial to complete dehydration took place. The mineral reacts with potassium acetate and ethylene glycol. The expansion of its lattice after glycolation is incomplete and an effect similar to a partial dehydration is produced. A partially dehydrated natural sample was interpreted with the aid of the calculated Allegra's mixing function as a 4:6 assemblage of hydrated and dehydrated halloysite.

The halloysite clay and the smectite underneath were most probably derived from serpentinite as is indicated by the position and texture of the clay, the mineral composition of its insoluble residue, the trace element distribution, and the demonstrated thermodynamic feasibility of the chrysotile-halloysite transformation.

KEY WORDS: Halloysite, Pt Macquarie, weathered profile, origin, interstratification (7 & 10 \AA).

Introduction

Along the beaches at Pt Macquarie on the northern coast of N.S.W., there is an outcropping suite of ophiolitic rocks comprising banded cherts, shales, manganese silicate rocks, pillowed and brecciated extrusive rocks, mafic and ultramafic dykes, dioritic intrusive rocks, and a serpentinized ultramafic complex (Fig. 1). The rocks are highly altered and mineral assemblages are characteristic of prehnite-pumpellyite, greenschist and glaucophane schist facies of metamorphism. The complex has been described by Barron *et al.* (1976).

At places, soft argillaceous rocks occur which are constituted predominantly of clay minerals. Of these the majority are associated with chert, X-ray powder diffraction analysis showed them to be composed of kaolinite and/or chlorite together with micaceous mineral. Originally they were shales and slates. Argillized mafic volcanic rocks outcrop at Shelly Beach and Tacking Point. Their main, and sometimes sole, constituent is smectite.

The most interesting clay mineral occurrence was found on a slope above Rocky Beach, which is situated about 1 km SE from the mouth of the Hastings River (grid reference 928/219 on Pt Macquarie 1:25 000). There, halloysite occurs in a prominent horizon of blue clay about 2 m thick which is obviously part of a deeply weathered profile. This occurrence differs from all hitherto recorded occurrences in N.S.W. (Loughnan & Craig 1960; Rattigan 1967).

Clay mineral composition of the profile

The profile with halloysite clay is situated above serpentinite which contains nearby two lenses of glaucophane-bearing schists. Rare but significant local concentrations of compact white magnesite and rare macroscopic chromite were found in the serpentinite. The profile itself comprises the following lithological units (Fig. 2):

- | | |
|-------------|--------------------------------------------------------------------------------------------|
| 0-7 m | Clay: white or light grey or brown occasionally mottled, laminated and sandy or silty (6). |
| 7-10.3 m | Clay: white, red-brown mottled (5). |
| 10.3-12.4 m | Blue clay: ferruginous, purple at the top (4). |

* Geological & Mining Museum, Geological Survey of New South Wales, 36-64 George St., Sydney, N.S.W. 2000.

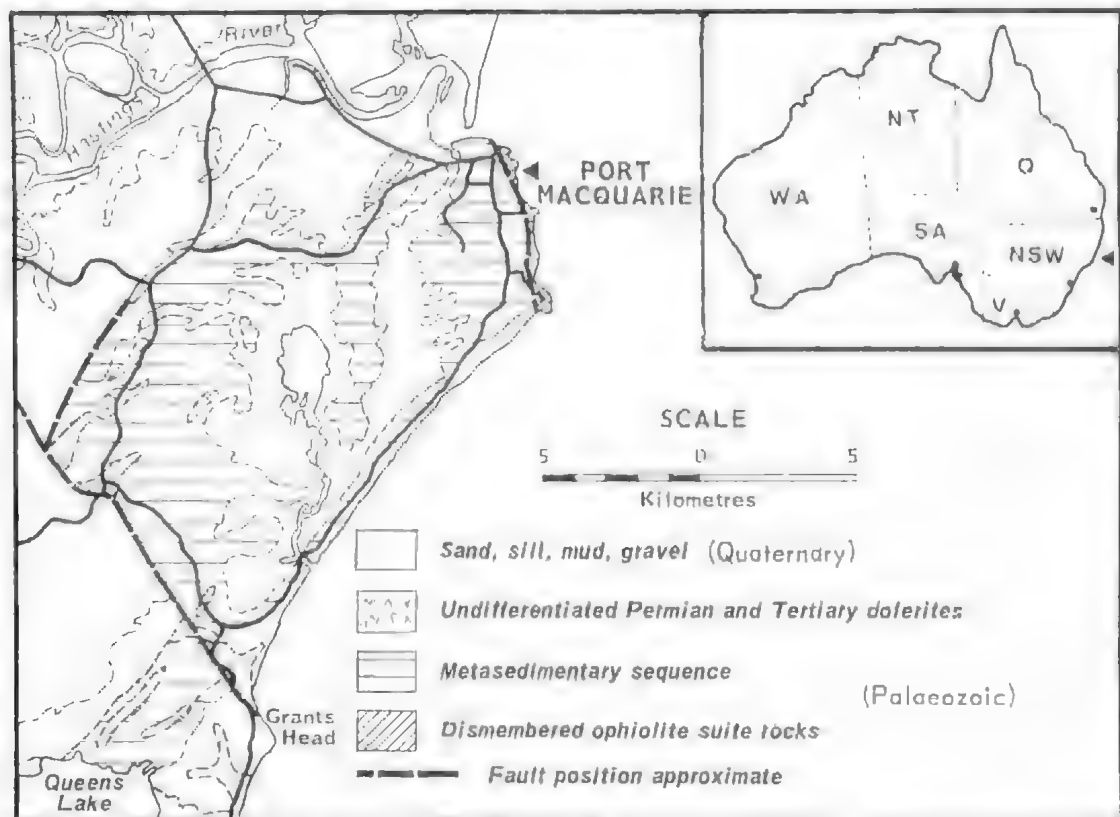


Fig. 1. Sketch map showing generalized geology of Pt Macquarie area and location of weathered profile (modified from Barron *et al.*, 1976).

- | | |
|-------------|--------------------------------------------------------------|
| 12.4–12.9 m | Clay: mottled, light brown, dark brown and red, white (3). |
| 12.9–13 m | Clay: dark grey and brown, almost black (2). |
| 13–14.1 m | Serpentinite: disintegrated, fragmentary, and cavernous (1). |
| 14.1 m | Serpentinite: fresh. |

X-ray powder diffraction data were obtained by examining oriented as well as unoriented specimens taken from all members of the profile. Clay fractions less than $2\ \mu\text{m}$ and less than $0.2\ \mu\text{m}$ (e.s.d.) were studied. The estimation of the quantity of clay minerals was based on the comparison of diffraction intensities of diagnostic basal reflections. Although the results are semiquantitative, the relative differences between samples are reasonably reliable.

The clay mineral distribution throughout the section as revealed by the examination of the less-than- $2\ \mu\text{m}$ fraction of 24 samples is shown in Fig. 2. The interpretation of X-ray diagrams was aided by the study of the less-than- $0.2\ \mu\text{m}$ fraction. Thus, the micaceous mineral is considered to be illite, as its abundance in the finer

fraction is much higher. It seems also that for the less-than- $0.2\ \mu\text{m}$ fraction the boundary between zone 4 and 5 is slightly higher.

Four clay mineral assemblages can be clearly distinguished in the section. Their typical X-ray diagrams are represented in Fig. 2. From the bottom to the top they are:

- (i) Mainly smectite with some illite and serpentine mineral. The last increases towards fresh serpentinite and is absent in the clay fraction. Lithological units 1, 2 and partly 3.
- (ii) Halloysite, predominantly as a sole clay mineral, at the bottom sometimes with a small quantity of smectite. Part of lithological unit 3 and lithological unit 4.
- (iii) Kaolinite, mainly as the only clay mineral, occasionally with a small quantity of smectite and more frequently with a small quantity of illite, Lithological unit 5.
- (iv) Kaolinite-illite, with the former slightly dominating over the latter. In the very top part there is a minute admixture of smectite. Lithological unit 6.

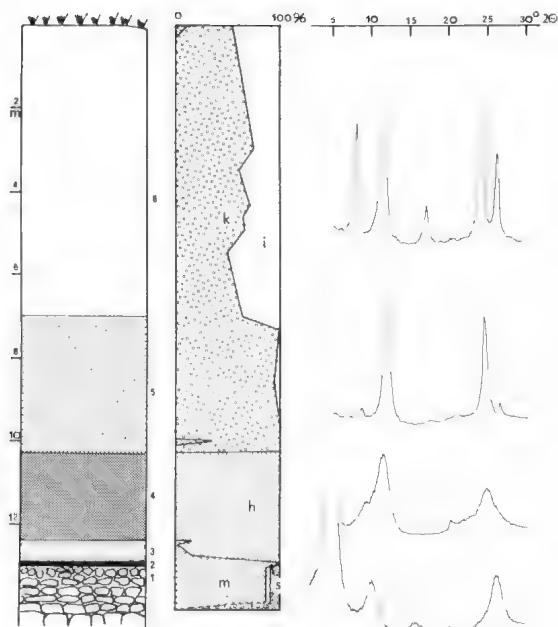


Fig. 2. Lithological sequence, clay mineral distribution and X-ray diffraction traces of the four clay mineral assemblages (CuK α radiation), s = serpentine mineral, m = smectite, i = illite, h = halloysite, k = kaolinite. Clay mineral distribution is normalized plot of diffraction intensities of first basal reflections. Numbers on right refer to lithological units established in profile.

The clay mineral composition of the profile is also well illustrated by differential thermal analysis (Fig. 3) which included a specimen of fresh serpentinite (Fig. 3, curve 1). The smectite clay of unit 1 produced a fairly atypical curve without a clearly defined dehydroxylation maximum (Fig. 3, curve 2) despite its well-defined diffractometer trace. The three remaining curves of Fig. 3 are in good agreement with the results of X-ray diffraction analysis.

Mineral characteristics of the halloysite

The halloysite clay can be cut by a knife when wet and readily disintegrates in water. When left in the laboratory for some time it develops desiccation cracks. It has a prominent planar structure which is caused by alternation of thin and rather irregular dark and light parallel layers. The overall colour impression is grey with bluish and purple tints. No distinct mineral grains are visible to the naked eye. Under a binocular stereomicroscope it can be seen that the parallel structure is due to dark, very small, red brown or dark grey grains arranged in thin bands and embedded in a light

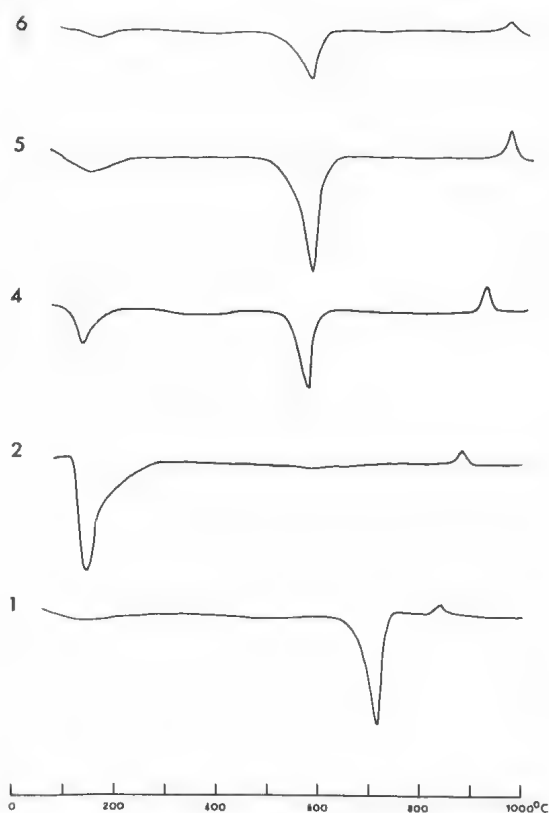


Fig. 3. Differential thermal curves for natural samples of individual lithological units. Numbers refer to those of Fig. 2.

coloured, white and grey massive matrix. The white parts of the matrix appear to form tiny elongated lenses within the grey matrix. In a thin section cut across the banding the matrix is a colourless scarcely birefringent aggregate with fairly uniform extinction between crossed nicols. The colourless matrix is stained yellowish brown in elongated, generally parallel, thin patches. There are many fine almost opaque grains either disseminated throughout the rock, or arranged in parallel clusters and patches. Some of these grains are red-brown translucent and anisotropic in polarized light. The clay is highly magnetic. A powder made of it by grinding is wholly attracted to a permanent magnet.

The form of the halloysite particles could be clearly seen under the scanning electron microscope (Fig. 4). Fresh fragments of natural clay were used as specimens. The halloysite clay had a different tubular structure in each of the two types of clayey matrix. Halloysite in the tiny white lenses within the grey

massive matrix is well developed in elongated tubes with aspect ratios mostly higher than 10:1 and reaching 30:1 in several cases. The diameter of the tubes is about 0.2 μm . Some

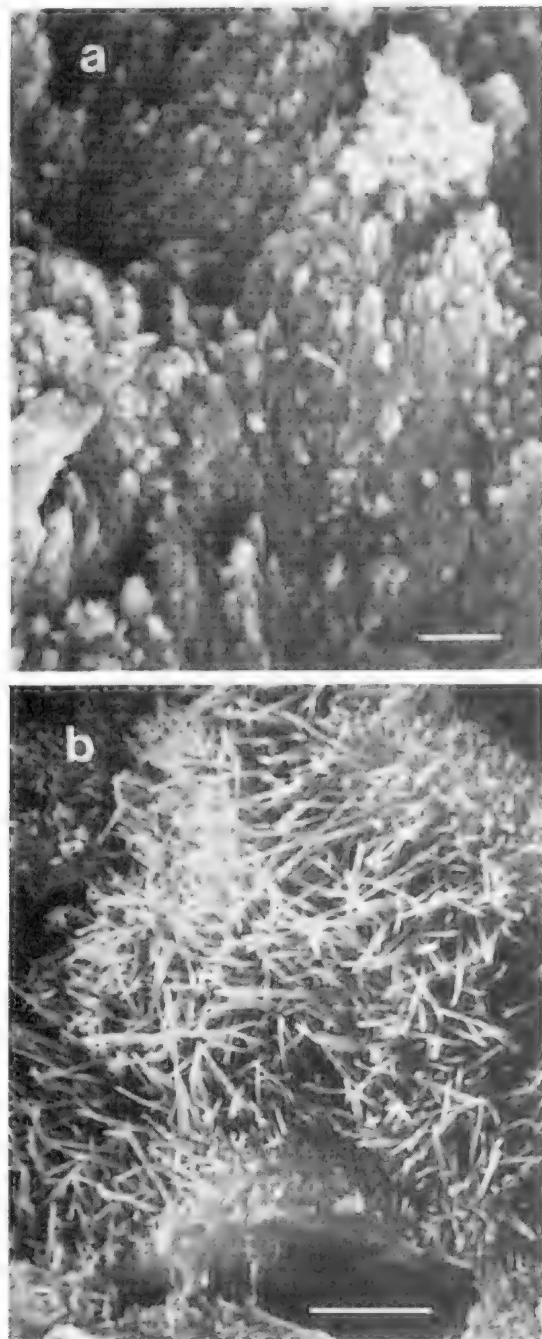


Fig. 4. Scanning electron micrographs of natural surfaces of halloysite clay: (a) halloysite in grey matrix, (b) halloysite in small white lenses. In (a), bar equals 1 μm ; in (b) bar equals 5 μm .

TABLE 1. *Halloysite, Rocky Beach, Pt Macquarie.*

Chemical analysis		Number of ions per 18 O (OH)	
	%		
SiO ₂	44.1	Si	3.807
TiO ₂	0.01	Ti	0.001
Al ₂ O ₃	37.0	Al	3.766
Fe ₂ O ₃	0.58	Fe ^{III}	0.038
FeO	0.02	Fe ^{II}	0.001
MnO	0.01	Mn	0.001
MgO	0.036	Mg	0.006
CaO	0.03	Ca	0.003
SrO	0.001		
BaO	0.003		
Na ₂ O	0.04	Na	0.007
K ₂ O	0.01	K	0.001
P ₂ O ₅	0.29		
H ₂ O ⁺	16.2	OH	9.322 (8.00)
H ₂ O ⁻	2.28	H ₂ O	0.657 (1.3)
CO ₂	0.01		
S	0.03		
100.6			

T. D. Rice, Analyst, Chemical Laboratory, N.S.W. Department of Mineral Resources.

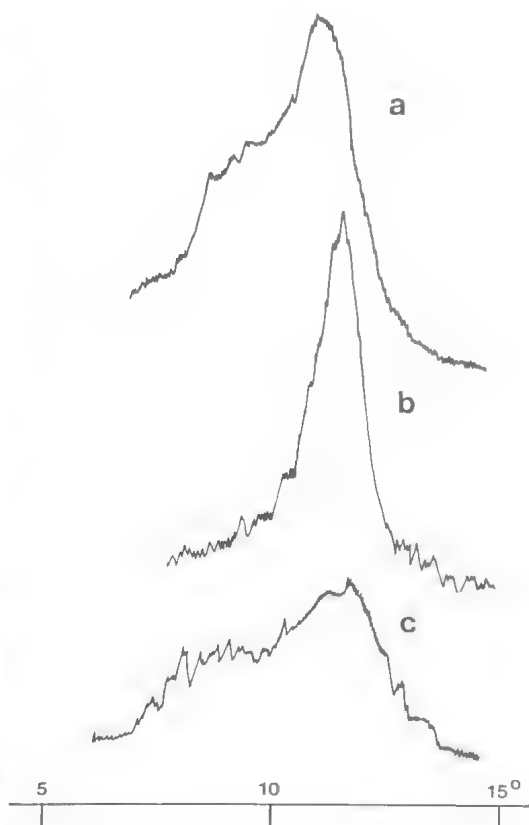


Fig. 5. Diffractometer traces of oriented aggregates of halloysite. (a) natural specimen, (b) bench dry, (c) glycolated. CuK α radiation.

suitably oriented particles show the hollow in the tubes. The form and arrangement of the tubes is indicative of unrestricted crystallization in an open space. In the grey matrix, halloysite particles are arranged in a much denser aggregate. The individual tubes are adjacent and less well developed. The aspect ratio is much smaller, less than 10:1. The diameter of the tubes is the same as in the first type, viz., 0.2 μm . The tubes are markedly aligned and appear to be somewhat flattened. Scanning electron micrographs of specimens from above the halloysite clay were also taken. Typical kaolinite flaky morphology of particles was revealed with occasional halloysite tubes occurring immediately above the halloysite horizon.

The chemical composition of the halloysite is given in Table 1. A conspicuous feature of the analysis is the high content of H_2O^+ . As there is no indication of the presence of any other crystalline component in this fraction, the excess water which amounts to about 0.7 molecules belongs most probably to halloysite. This is not an uncommon situation: high temperature water values are larger in all but two of the nineteen chemical analyses of halloysites compiled by Weaver & Pollard (1973), who attribute the excess to water trapped between layers during dehydration. In Table 1 the excess of water above $(\text{OH})_2$ was combined with the amount of water corresponding to H_2O^- . The value of 1.3 H_2O thus obtained is intermediate between the hydrated and dehydrated form of halloysite.

X-ray powder diffraction traces of halloysite mainly indicate a dehydrated form (metahalloysite) (Fig. 5); it is however very likely that the halloysite in natural samples was originally hydrated and later lost water in the process of storage and handling. Some oriented diagrams, e.g. that in Fig. 5a, show a strongly asymmetrical 001 peak with a distinct tail towards lower θ angles. Sometimes there is even a subsidiary peak in the "tail" at about 9.5 Å.

Despite a reaction with ethylene glycol the expansion of the halloysite lattice is incomplete. Instead of a single 7.7 Å reflection of the air-dry specimen, glycolation produces a broad band with two maxima at 10.0 and 7.7 Å (Fig. 5c). Intercalation with potassium acetate (Wada 1961; Miller & Keller 1963) produced a strong peak at 14.2 Å (Fig. 6d). After washing and keeping the specimen wet this spacing changed to 10.2 Å (Fig. 6e). When ethylene glycol was applied on the wet speci-

men (the specimen slurry was on a membrane filter and ethylene glycol was filtered through it) immediate recording showed a peak at 11.2 Å (Fig. 6f). Washed and air-dried specimens displayed a broad peak with a tail towards lower diffraction angles and with maximum at 7.9 Å. The same specimens when glycolated in the usual manner (left overnight above ethylene glycol in a desiccator) yielded some-

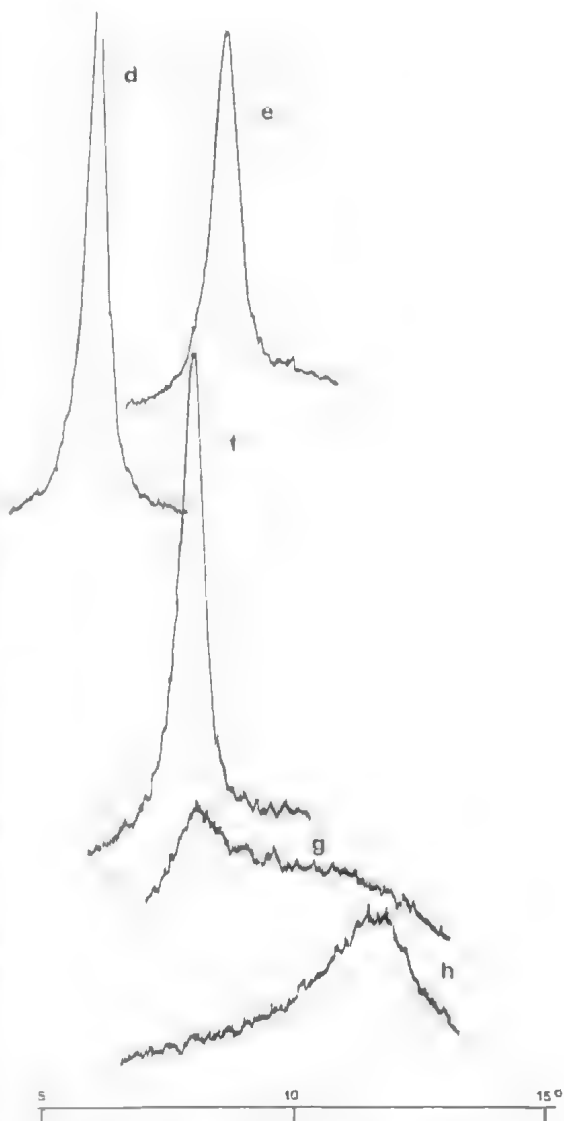


Fig. 6. Diffractometer traces of oriented aggregates of halloysite: treated with (d) potassium acetate, (e) washed and kept wet, (f) glycolated and X-rayed immediately, (g) washed, air-dried and later glycolated (thin specimen), (h) same, but thick specimen. $\text{CuK}\alpha$ radiation.

what erratic results related to the thickness of the oriented specimens: extremely thin specimens expanded to about 11 Å (Fig. 6g), thick specimens showed minimal expansion with a peak at 7.6 Å (Fig. 6h) and specimens of intermediate thickness exhibited a broad flat peak around 8 Å and an indistinct broad peak at 11 Å. The obvious inference is that ethylene glycol vapour was able to penetrate only a thin surface layer of halloysite spread on a glass slide. Even in the case of the very thin specimen there is a tail of increased intensity towards higher diffraction angles with a convex appearance suggesting the presence of a peak of non-expanded dehydrated halloysite.

Thus incomplete glycolation with or without previous potassium acetate intercalation produced an effect similar to that taking place during dehydration of hydrated halloysite. Brindley & Goodyear (1948) first noted that the 001 reflections of halloysite which loses water, appear in two narrow regions of spacings within a band of increased intensity. Churchman *et al.* (1972) concluded that dehydration of halloysite takes place through an interstratification in which there is a partial segregation of the two basic layer types, 7.2 and 10.1 Å, respectively.

The interstratification of 7 and 10 Å layers was studied in detail and the results were summarized elsewhere (Slansky 1980). Here, suffice it to say that by calculating Allegra's mixing function (Allegra 1961; Cesari *et al.* 1965) for different types of interstratification, viz., with maximum degree of randomness, with a

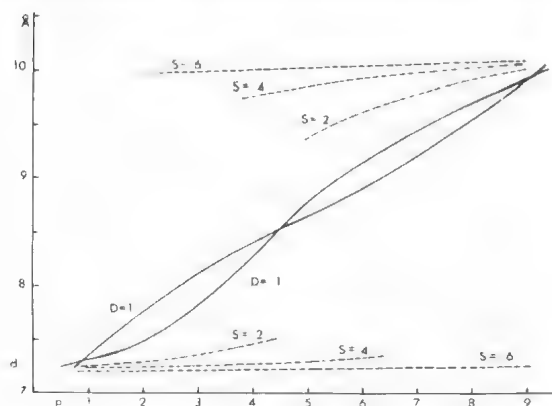


Fig. 7. Peak migration of Allegra's mixing function with composition for 10 and 7 Å layers. D = degree of randomness defined as P_{AA}/P_A , S = degree of segregation defined as $1 - P_{AA}/(1 - P_A)$, where P_{AA} is probability that 10 Å spacing succeeds another and P_A is frequency of same spacing.

low degree of randomness, with moderate degrees of segregation, and with a high degree of segregation, it was possible to simulate the diffraction effects produced by assemblages of the two layers mixed in various manners and proportions. Fig. 7 summarizes the results in terms of 001 peak movement with composition expressed as the fractional proportion of the 10 Å layer. The diagram shows that even in the case of a moderate degree of segregation (such as 0.2) there is a tendency for the reflections to be grouped near the values of the two layers and the peak position corresponding to the prevailing (hydrated or dehydrated) form is only slightly influenced by the presence of the other one. In a rather narrow interval, both peaks are present on the diffraction pattern together. This interval increases with the degree of segregation. The multiple peaks a, c, and g of Figs. 5 and 6 belong to this interval, and the peak a of natural halloysite can be interpreted as 4:6 assemblage of hydrated and dehydrated halloysite with some segregation.

Origin of the halloysite

Harrison (1955) reported an extensive lateritic profile over serpentinite near Pt Macquarie in connection with an examination of a secondary enrichment of nickel and cobalt. The laterite was formed, according to this author, by *in situ* weathering of serpentinite involving almost complete removal of magnesia and a substantial reduction in SiO_2 along with an increase in the Al_2O_3 and Fe_2O_3 contents. Near the base of the lateritic profile there is a noticeable concentration of cobalt, nickel and chromite. Cobalt was found in such a profile occurring a short distance south of Nobby's Point about 1886 (Jaquet 1898; Carne 1896) bound in wad. Some mining took place around the turn of the century, however the main ore utilized was iron (cf. MacNevin 1975). The main ore-producing deposits were in the town of Pt Macquarie.

Although all deposits mentioned above were found at more or less different spots than was the halloysite clay examined, its occurrence within the same weathering crust can be taken for granted. The considerable extension of the weathering crust coupled with the diversity of rocks along the coastline as documented by Barron *et al.* (1976), however, results in the problem of determining the parent rocks involved in the weathering at the halloysite occurrence.

The position of the halloysite clay, and in particular its occurrence immediately above serpentinite, and the proximity of two lenses of glaucophane schists suggests that halloysite could have been formed either from serpentinite or from a glaucophane schist. The latter possibility was favoured in the past (cf. Barron *et al.* 1976); however the present more detailed study has indicated that serpentinite is the more probable parent rock. This conclusion is based on several points:

1. The texture of the halloysite clay resembles that of a schistose serpentinite, as can be seen when comparing thin sections of the two rocks. The distribution of opaque grains of iron oxides is significant in this context. It is a well known fact that in the course of serpentinization only a small part of the iron from silicates of the serpentinite precursor enters the serpentine minerals. The rest forms a magnetite network the form of which is influenced by the structure of the rock. In the case of schistose serpentinite the grains or garlands of grains of magnetite are arranged in parallel bands, as are the iron oxide grains in the halloysite clay. The magnetite later can be altered (mainly oxidized) to other iron oxides or hydroxides.

2. The non-silicate fraction of the rocks separated as insoluble residue by HF treatment according to Norrish (1968) and as heavy portion by panning, was examined by X-ray powder diffraction. Hematite, some maghemite, magnetite, and a spinel (whose X-ray data point to a 8.295 ± 0.005 Å, i.e. a value within the range given by Hutchison (1972) for chromite), were identified in the fraction extracted from the halloysite clay. As was mentioned earlier, the halloysite clay is highly magnetic and this property is caused by magnetite and possibly maghemite. The association of hematite and spinels ends at the boundary between the halloysitic and kaolinitic clays.

3. A semi-quantitative analysis of minor and trace elements in the profile by optical emission spectrography, in particular the distribution of Ni, Co, Cr and Ti (Fig. 8) supports the idea that the kaolinite and halloysite assemblages were formed from different parent rocks. The base of the profile and the halloysite clay showed increased concentration of Ni and Cr, and to some extent also of Co. It is common knowledge that these elements have an increased abundance in ultrabasic rocks.

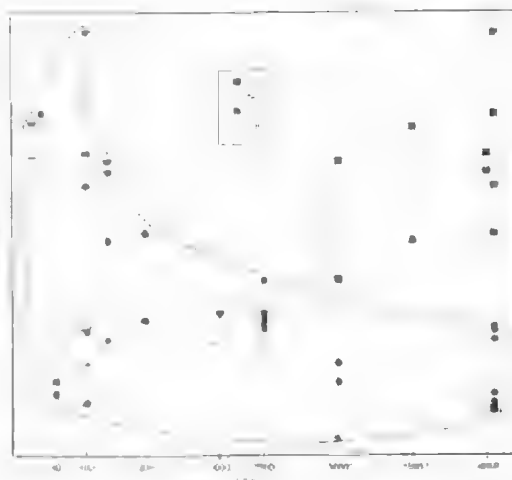
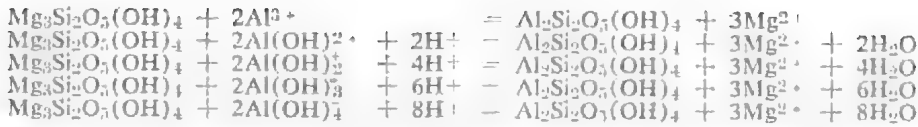


Fig. 8. Plot of distribution of four trace elements in weathered profile. Data are semi-quantitative based on optical emission spectrography (D. Karagolis, Chemical Laboratory, Department of Mineral Resources, N.S.W., Sydney). Envelopes were drawn arbitrarily around Ni, Co, Cr, and Ti to show concentration of three elements increasing with depth and titanium following an opposite pattern.

Nickel as well as cobalt may even be enriched during weathering of these rocks. Above the halloysite clay, Ti is the dominant trace element. Co is absent, Ni is very low until eventually disappearing in the upper part of the profile, and Cr becomes much lower.

4. Several instances of halloysite formed from ultrabasic rocks by weathering or hydrothermal alteration were reported in the literature. Notable are the occurrences in Yugoslavia (Maksimovic & Crnkovic 1968, Maksimovic & Brindley 1980), and in the U.S.S.R. (Ginzburg & Rukavishnikova 1951). When weathering is involved, an increase in iron and aluminium takes place. The level of the increase of the last is controlled by the conditions of weathering processes according to Maksimovic & Crnkovic (1968). Weathering products formed in a tropical climate with a high rainfall have a higher content of alumina.

With respect to the evidence so far adduced the proposition that the parent rock of the halloysite clay was serpentinite appears very probable. In order to examine further the validity of this proposition the mutual stability of a serpentine mineral (chrysotile) and halloysite at normal temperature and pressure was assessed. Considering Al^{3+} and some Al-hydrated species as mobile reactive components a series of reactions may be written:



The equilibrium constants (in log) of these reactions calculated with Gibbs free energies given in Table 2 are:

$$\begin{aligned} 3 \log a\text{Mg}^{2+} - 2 \log a\text{Al}^{3+} &= +23.18 \\ 3 \log a\text{Mg}^{2+} - 2 \log a\text{Al}(\text{OH})_3 + &= -2\text{pH} + 32.25 \\ 3 \log a\text{Mg}^{2+} - 2 \log a\text{Al}(\text{OH})_3 &= -4\text{pH} + 42.90 \\ 3 \log a\text{Mg}^{2+} &= -6\text{pH} + 54.64 \\ 3 \log a\text{Mg}^{2+} - 2 \log a\text{Al}(\text{OH})_3 &= -8\text{pH} + 69.62 \end{aligned}$$

where *a* is activity.

TABLE 2. Gibbs Free Energies at 25°.

Species	ΔG _f , 298 (kJ/mol)	Source
chrysotile	-4034.024	Robie <i>et al.</i> (1979)
halloysite	-3780.713	
kaolinite	-3799.364	
Mg ²⁺	-454.800	
Al ³⁺	-489.40	Naumov <i>et al.</i> (1971)
Al(OH) ₃ ^{cr}	-700.65	
Al(OH) ₃ ^{aq}	-907.38	
Al(OH) ₃ ^{aq}	-1111.06	
Al(OH) ₃ ^{aq}	1305.4	Robie <i>et al.</i> (1979)
H ₂ O	-237.141	

Fig. 9 is a three-dimensional plot of the mutual stability of the two minerals based on these values. The plot shows that the formation of halloysite from chrysotile (and possibly from other serpentine minerals) is feasible at low concentrations of Al such as encountered in natural conditions in fluids at normal temperature and pressure, and at realistic pH values. For example the chemical composition of groundwater from serpentinite which was recorded by White *et al.* (1963) as having pH 8.3 and Al and Mg molalities 7.4×10^{-6} and 2.1×10^{-3} , respectively. A point corresponding to these values falls within the field of halloysite indicating that in respect to this water, halloysite is a more stable mineral than chrysotile.

Regarding the mechanism of the alteration of a serpentine mineral to halloysite, the dissolution experiments done on a series of sheet Mg minerals (including antigorite) by Lin & Clemency (1981) are of consequence. They found that the dissolution of these minerals is incongruent, i.e. Mg is released more rapidly from the octahedral sheets than is Si from the tetrahedral sheets. Thus it can be argued that the transformation to halloysite might involve only the exchange of Mg for Al in the octahedral sheet while the tetrahedral sheet is left intact. Moreover, if the original serpentine mineral was chrysotile, its tubular structure could be inherited by halloysite. Volume changes resulting from the alteration are small as the molar volumes of halloysite and serpentine minerals are very similar.

Above the halloysite clay the clay mineral assemblage which is dominated by kaolinite indicates a different parentage. Anatase and quartz were identified in the insoluble residue of unit 5 and the lower part of unit 6. In the upper part of the profile anatase is absent, Ti

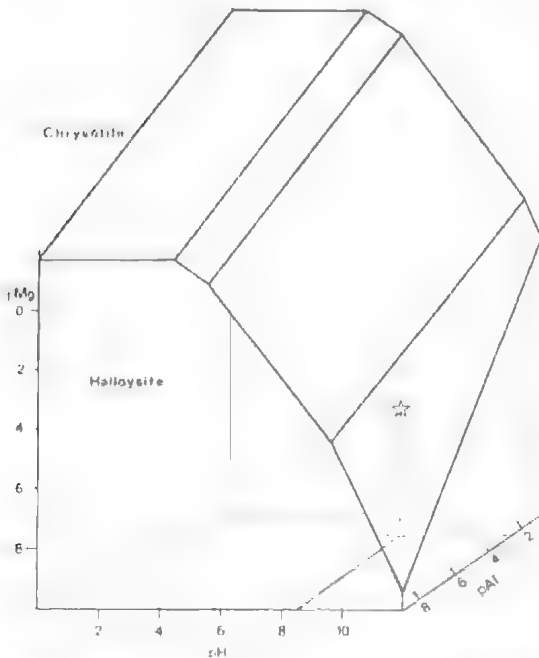


Fig. 9. Stability diagram of halloysite-chrysotile at 25°C temperature and 1 atm pressure. Star corresponds to composition of water from a serpentinite as reported by White *et al.* (1963). p is negative logarithm of activity.

is the dominant trace element (see Fig. 8) obviously related to anatase and possibly further up to illite. The kaolinite clays were formed probably from metagraywacke, such as is found unaltered in an adjacent small gully. A detailed sketch of the lithologies exposed in this gully can be found in the paper by Barron *et al.* (1976).

Acknowledgments

I am indebted to E. Scheibner (Geological Survey of N.S.W.) who drew attention to the occurrence of the blue clay and to R. C. Kuhnelt (Department of Mineral Technology, Delft University of Technology, Holland) for

the SEM photographs. My thanks are also due to T. D. Rice (Chemical Laboratory, N.S.W. Department of Mineral Resources) for the chemical analysis of the halloysite, and to D. Karaolis from the same laboratory for spectrographic analyses. The manuscript benefited from discussions with G. Hladky (CSIRO Institute of Earth Resources, Sydney) and from a constructive criticism provided by L. M. Barron (Geological Survey of N.S.W.). A Ferguson helped with editing the manuscript. Two referees proposed some emendations of the text which were gratefully accepted. Published with permission of the Secretary, NSW Dept of Mineral Resources.

References

- ALLEGRA, G. (1961) A simplified formula for the calculation of X-ray intensity diffracted by a monodimensionally disordered structure. *Acta Crystallogr.* **14**, 535.
- BARRON, B. J., SCHEIBNER, E. & SLANSKY, E. (1976) A dismembered ophiolite suite at Port Macquarie, New South Wales. *Rec. geol. Surv. N.S.W.* **18**, 69-102.
- BRINDLEY, G. W. & GOODYEAR, J. (1948) X-ray studies of halloysite and metahalloysite II. The transition of halloysite in relation to relative humidity. *Mineralog. Mag.* **27**, 407-422.
- CARNE, J. E. (1897) Appendix 7. Report on the geology and mineral resources of the coast between Port Macquarie and Cape Hawke. *A. Rep. Dep. Mines N.S.W. for 1896*, 102-107.
- CESARI, M., MORELLI, G. L. & FAVRETTO, L. (1965) The determination of the type of stacking in mixed-layer clay minerals. *Acta Crystallogr.* **18**, 189-196.
- CHURCHMAN, G. J., ALDRIDGE, L. P. & CARR, R. M. (1972) The relationship between the hydrated and dehydrated states of halloysite. *Clays Clay Min.* **20**, 241-246.
- GINZBURG, I. I. & RUKAVISHNIKOVA, I. A. (1951) Mineraly drevney kory vyvetriveniya Urala. (Ac. Sci.: Moscow.)
- HARRISON, E. J. (1955) Port Macquarie iron oxide deposits. *A. Rep. Dep. Mines N.S.W. for 1951*, 71-73.
- HUTCHISON, C. S. (1972) Alpine-type chromite in north Borneo, with special reference to Darvel Bay. *Am. Miner.* **57**, 835-856.
- JAQUET, J. B. (1898) Appendix 17. Report on cobalt deposits at Port Macquarie. *A. Rep. Dep. Mines N.S.W. for 1897*, 117-180.
- LIN, F. C. & CLEMENCY, C. V. (1981) The dissolution kinetics of brucite, antigorite, talc, and phlogopite at room temperature and pressure. *Am. Miner.* **66**, 801-806.
- LOUGHNAN, F. C. & CRAIG, D. C. (1960) An occurrence of fully hydrated halloysite at Muswellbrook, New South Wales. *Ibid.* **45**, 738-790.
- & ROBERTS, F. I. (1981) The natural conversion of ordered kaolinite to halloysite (10Å) at Burning Mountain near Wingen, New South Wales. *Ibid.* **66**, 997-1005.
- MACNEVIN, A. A. (1975) Wollomin—Texas Block, Great Serpentine Belt. In N. L. Markham, H. Basden, (Ed.), "The Mineral Deposits of New South Wales." (Geol. Survey of N.S.W.: Sydney.)
- MAKSIMOVIC, Z. & CRNKOVIC, B. (1968) Halloysite and kaolinite formed through alteration of ultramafic rocks. *Trans. 23rd Int. geol. Congr. Prague* **14**, 95-105.
- & BRINDLEY, G. W. (1980) Hydrothermal alteration of a serpentinite near Takovo, Yugoslavia, to chromium-bearing illite/smectite, kaolinite, tosudite, and halloysite. *Clays Clay Min.* **28**, 295-302.
- MILLER, W. D. & KELLER, W. D. (1963) Differentiation between endellite-halloysite and kaolinite by treatment with potassium acetate and ethylene glycol. *Ibid.* **10**, 244-253.
- NAUMOV, A. B., RYZHENKO, B. N. & KHODAKOVSKIY, I. L. (1971) Spravochnik Termodinamicheskikh Velitchin. (Atomizdat: Moscow.)
- NORRISH, K. (1963) Some phosphate minerals of soils. *Trans. 9th Congr. Soil Sci.* **11**, 713-723.
- RATTIGAN, J. H. (1967) Occurrence and genesis of halloysite, Upper Hunter Valley, New South Wales, Australia. *Am. Miner.* **52**, 1795-1805.
- ROBIE, R. A., HEMINGWAY, B. S. & FISHER, J. R. (1979) Thermodynamic properties of minerals and related substances at 298.15K and 1 bar (10^5 Pascals) pressure and at higher temperatures. *Bull. U.S. geol. Surv.* **1452**.
- SLANSKY, E. (1980) The interstratification of 10 and 7Å layers; Allegra's mixing function for random and partially ordered stacking. *Abstr. 4th Natn. Conf. on X-ray Analysis, Canberra*, 14.
- WADA, K. (1961) Lattice expansion of kaolin minerals by treatment with potassium acetate. *Am. Miner.* **46**, 78-91.
- WEAVER, C. E. & POLLARD, L. D. (1973) "The chemistry of Clay Minerals." (Elsevier: Amsterdam, London, New York.)
- WHITE, D. E., HEM, J. D. & WARING, G. A. (1963) Data of geochemistry. Sixth Ed. Chap. F., Chemical composition of subsurface waters. *Prof. Pap. U.S. geol. Surv.* **440 F**.

**ARIUS GRAEFFEI AND ARIUS ARMIGER: VALID NAMES FOR TWO
COMMON SPECIES OF AUSTRALO-PAPUAN FORK-TAILED CATFISHES
(PISCES, ARIIDAE)**

BY PATRICIA J. KAILOLA

Summary

Arius graeffei Kner & Steindachner 1866 is a senior synonym of *Arius australis* Günther 1867 and *Arius armiger* De Vis 1884 is a senior synonym of *Arius stirlingi* Ogilby 1898. Diagnostic descriptions and distributions of *A. graeffei* and *A. armiger* are presented. Taylor's (1964) conclusions that *A. australis*, *A. stirlingi* and *A. leptaspis* represent one species are not supported.

ARIUS GRAEFFEI AND ARIUS ARMIGER: VALID NAMES FOR TWO COMMON SPECIES OF AUSTRALO-PAPUAN FORK-TAILED CATFISHES (PISCES, ARIIDAE)

by PATRICIA J. KAILOLA*

Summary

KAILOLA, PATRICIA J. (1983) *Arius graeffei* and *Arius armiger*: valid names for two common Australo-Papuan fork-tailed catfishes (Pisces, Ariidae). *Trans. R. Soc. S. Aust.* **107**(3), 187-196, 30 November, 1983.

Arius graeffei Kner & Steindachner 1866 is a senior synonym of *Arius australis* Günther 1867 and *Arius armiger* De Vis 1884 is a senior synonym of *Arius stirlingi* Ogilby 1898. Diagnostic descriptions and distributions of *A. graeffei* and *A. armiger* are presented. Taylor's (1964) conclusions that *A. australis*, *A. stirlingi* and *A. leptaspis* represent one species are not supported.

KEY WORDS: Northern Australia, Papua, fork-tailed catfishes, Ariidae.

Introduction

Although fork-tailed catfishes are abundant in the rivers, estuaries and muddy coastal waters of northern Australia and New Guinea, the taxonomy of this fauna is poorly understood. The need for a serious study of the family is reflected in the history of the species listings for Australia; only 8 species are common to the listings of McCulloch (1929—total of 12 species), Munro (1957—11 species) and Whitley (1964—13 species).

My studies over the past few years have revealed the existence of eighteen valid species in Australia: six of them are undescribed, and the nomenclature of the described species is confused. The present paper seeks to unravel the confusion surrounding two common species and to redefine those species by a new combination of characters.

In his study of the fishes of Arnhem Land, Taylor (1964) suggested that *Arius australis* Günther 1867, *A. leptaspis* (Bleeker 1862) and *A. stirlingi* Ogilby 1898 may represent only population divergence within one species. Lake & Midgley (1970), Lake (1971) and Pollard (1974, 1980) followed Taylor and considered *A. leptaspis* (Bleeker) a single widely-dispersed Australo-papuan catfish (although Lake cautions that a detailed study of large numbers of varying sizes of catfish over the whole range of their distribution is needed to settle the matter).

Materials and Methods

In this study, I have endeavoured to examine specimens from the recorded range of each species.

The specimens reported here are located in the following collections: American Museum of Natural History (AMNH); Australian Museum, Sydney (AMS); British Museum (Natural History) (BMNH); CSIRO Division of Fisheries (CSIRO); Macleay Museum, University of Sydney (MMUS); Museum National d'Histoire Naturelle, Paris (MNHN); Naturhistorisches Museum, Vienna (NMW); Queensland Museum (QM); Rijksmuseum van Natuurlijke Historie, Leiden (RMNH); South Australian Museum (SAM); Western Australian Museum (WAM).

Measurements were made from the left side of the body with needle-point calipers to the nearest 0.1 mm, but in the case of very large fishes, standard lengths (SL) were obtained by use of a mm-graduated ruler. The methods of measurement and counting follow Hubbs and Lagler (1958) with the following additions: width of the maxillary tooth band—broadest width measured across curve of the tooth band; length of the maxillary tooth band—longest distance of band, usually across each lateral arm; "interdorsal" fin space—distance between insertion point of last dorsal fin ray and anterior of the adipose fin; length of occipital process—from base of the bone where it meets the dorsomedian head groove to its most posterior point where it meets the predorsal plate; breadth of occipital process—widest distance at base of the process where it meets the main body of the head shield;

* Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001.

maxillary barbel length—distance from insertion point of the barbel to its tip; free vertebral count—total number of vertebrae from the first unfused vertebra behind the Weberian Apparatus to the last vertebra at the tail base (urostyle included); made from x-rays.

Counts, using a needle probe, were made of the dorsal, anal and pectoral fin elements and of the gill rakers.

Results

I find that *A. graeffei*, *A. leptaspis* and *A. armiger* are all valid species. Furthermore, the names *Arius australis* Günther 1867 and *A. curtisii* Castelnau 1878 are junior subjective synonyms of *A. graeffei* Kner & Steindachner 1866; the name *Arius stirlingi* Ogilby 1898 is a junior subjective synonym of *A. armiger* De Vis 1884.

Taylor (1964) identified 12 ariid specimens from Oenpelli as *A. australis*, one from Roper River and 14 from East Alligator River as *A. leptaspis*. He lacked *A. stirlingi* specimens. From information I supplied on distinguishing characters, Janet Gomon (U.S. National Museum) examined Taylor's specimens and reported that the 12 Oenpelli specimens identified as *A. australis* are *A. leptaspis* Bleeker, and that the Roper River and East Alligator River specimens identified as *A. leptaspis* are an undescribed *Arius* (*Arius* sp. 1) found in freshwater from the Roper River westward to the Ord River (W.A.). Taylor's figures (pp. 74, 80, 82) and species analysis are therefore not of *A. australis* (= *graeffei*) (see Table 1 and Figure 2 for comparison). What Lake, Midgley and Pollard have called *A. leptaspis* therefore, could have been either *A. graeffei*, *A. leptaspis*, *Arius* sp. 1 or *A. armiger*. Pollard has reproduced Taylor's figure of *A. leptaspis* (1980: 89). Grant (1978) consistently followed Munro (1957) and used *Neonarius australis*.

Arius graeffei Kner & Steindachner 1866

FIGS 1, 2; Tables 1, 2.

Arius graeffei Kner & Steindachner 1866: 383, fig. 12 (Samoa—locality doubtful, probably northern Australia).

Arius australis Günther 1867: 103, fig. 1 (Ash Island, Hunter River, N.S.W.).

Arius curtisii Castelnau 1878: 236 (Moreton Bay, Queensland).

Material examined: Holotype of *A. graeffei*: NMW 67 152, unknown locality, 252 mm SL; two syntypes of *A. australis*: BMNH 1866.2.13.4, Ash Island, Hunter R., N.S.W., no date, Scott,

275 mm SL and BMNH 1866.6.19.7, same data, 380 mm SL; syntype of *A. curtisii*: MNHN B.693, Moreton Bay, Qld, no date, Curtis, 144 mm SL; and 46 additional specimens from the following locations: N.S.W.: 6, Clarence R., 292–336 mm SL; 3, MUMS F.154, Richmond R., 197–207 mm SL; Qld: 4, QM 1.12001, 1.430, 1.9835, 1.9836, Brisbane R., 177–273 mm SL; 2, QM 1.16734, 1.16740, Boyne R., 117 and 297 mm SL; 1, QM 1.8606, Dawson R., 171 mm SL; 1, Chapman R., 236 mm SL; 1, QM 1.12758, Flinders R. near Maxwellton, 340 mm SL; N.T.: 6, Jabiru & Long Harry's Billabong, 178–323 mm SL; 3, Daly R., 83–310 mm SL; W.A.: 1, SAM F.4242, Ord R., 93 mm SL; 3, AMNH unreg., King R., 74–118 mm SL; 1, WAM P.25597–002, Fitzroy R., 329 mm SL; 3, AMNH unreg., Yeeda Creek, 88–113 mm SL; 1, WAM P.22876–001, Dampier, 358 mm SL; 4, AMS 1.18217–006, Maitland R., 77–88 mm SL; 1, WAM P.5807–001, Fortescue R., 376 mm SL; 2, AMNH unreg., Ashburton R., 85 and 292 mm SL; New Guinea: 1, Ihu, Gulf of Papua, 289 mm SL; 2, RMNH unreg., Jamoel Lake, 261 and 333 mm SL.

Definition: the combination of: raker-like processes present on the back of all gill arches; palatal teeth villiform and in transverse series of four oval patches; palatine patches larger than vomerine patches; maxillary barbels never reaching further than opposite base of dorsal fin spine; free vertebrae 45–48.

Description (based on 50 specimens): D:17; A: 15–19 (mean 17.4); P:10–11; GR (first arch) 17–22, mean 19 (total) of which 6–8 on upper limb; GR (last arch) 16–22, mean 19.1 (total); C: primary rays 7 + 8; V:6; number of free vertebrae 45–48.

Body robust, elongate (Fig. 1, Table 1, 2); anterior profile straight, moderately steep, elevated slightly before dorsal fin; mouth moderately broad and slightly curved, its width 2.1–2.7 (mean 2.4) in head length; snout sharply rounded, moderately fleshy upper lip extending beyond mouth gape, teeth usually concealed when mouth closed; shallow groove may be present on snout between nostrils; hind nostrils ovate-elliptical; anterior flap just concealing opening; eye ovate, dorso-lateral, free of orbit and positioned 1–1½ an eye diameter before mid-length of head. Jaw teeth in arched, curved bands, villiform: fine and sharp, depressible and in many (6–9) irregular series; length of maxillary tooth band 5.2–9.2 (mean 7.1) in its breadth; edentulous space separates each side of mandibular tooth band. Four patches of small, fine, sharp teeth on palate arranged transversely; vomerine patches ovate or rounded, separated at midline, noticeably smaller than outer oval palatine patches; with age vomerine and palatine patches often fuse

into one unit on one or both sides of palate or all four may coalesce to form single broad patch; two narrow smooth-edged longitudinal skin flaps well back on smooth palate.

Head shield (Fig. 2) finely and somewhat sharply granulated, granules arranged in series along each side of dorsomedian head groove, radiating outwards and over occipital process

TABLE 1. Relative body proportions of *Arius graeffei* and *Arius stirlingi*.

Character	n	<i>Arius graeffei</i>		Taylor's <i>A. australis</i>	n	<i>Arius armiger</i>	
		range	mean			range	mean
head in SL	50	3.0-3.8	3.4	3.0-3.5	30	3.2-4.0	3.5
eye 1. in head 1.	50	3.7-8.4	6.1	7.6-10.1	30	5.9-9.9	7.4
eye 1. in snout 1.	50	1.4-3.2	2.3		30	1.9-3.6	2.7
eye in bony inter-orbital width	48	1.1-3.0	2.1		28	1.6-3.3	2.3
occip. process width							
in process length	41	1.0-2.1	1.4		27	1.1-1.9	1.5
D. spine in hd. 1.	47	1.0-2.2	1.6	2.0-2.4	25	1.0-1.4	1.2
P. spine in hd. 1.	46	1.0-2.0	1.5	1.9-2.2	26	1.2-1.7	1.4
adipose fin base in D. fin base	50	1.0-2.0	1.3		30	0.8-1.9	1.2
adipose fin base in interdorsal space	50	2.4-5.9	3.4	2.6-3.3	30	2.0-5.1	3.0
caudal peduncle depth in its length	50	1.6-2.6	2.0		29	1.5-2.4	1.9
predorsal in SL	50	2.4-2.8	2.6	2.5-2.7	30	2.6-3.0	2.8
interdorsal in SL	50	3.1-4.1	3.6	3.3-4.2	30	3.3-4.3	3.8
longest barbel in SL	50	2.5-5.8	3.8		30	1.8-3.3	2.5
head height in head width	48	1.1-1.7	1.4		30	1.1-1.5	1.3
length mx tooth band in its width	35	5.2-9.2	7.1		26	4.3-10.6	8.3
eye in SL	50	13.7-26.6	20.2		30	20.1-33.3	26.2
mouth width in head 1.	27	2.1-2.7	2.4		15	2.0-2.3	2.1
bony interorb. width in head length	48	2.5-3.5	2.9		28	2.9-3.9	3.2
S.L. (mm)		74.2-380.0		201-435 mm		74.0-285.0	

TABLE 2. Percentage of standard length (SL) for specimens of *Arius graeffei* and *A. armiger*.

Character	n	<i>A. graeffei</i>	<i>A. graeffei</i> holotype	<i>A. australis</i> syntypes	<i>A. curtisi</i> syntype	n	<i>A. armiger</i>	<i>A. armiger</i> syntypes
SL range (mm)		74-376	252	275	380	144	74-285	134 148
head length	46	26-34	32	29	32	30	25-31	27 28
eye diameter	46	4-7	5	4	4	6	3-5	4 4
P fin spine 1.	42	15-23	20	19	19	22	17-23	- 23
D fin spine 1.	43	14-24	17	17	17	20	20-32	- -
adipose fin base 1.	46	5-11	8	8	6	10	8-13	8 6
anal fin base 1.	46	11-16	12	13	14	13	18-22	20 20
dorsal fin base 1.	46	9-13	10	10	12	12	10-13	11 11
interdorsal space	46	24-32	31	27	33	27	28-30	27 30
predorsal 1.	46	35-41	39	37	39	39	34-39	35 37
longest barbel	46	17-39	23	24	23	26	27-56	50 41
length occipital process	37	7-11	8	8	8	9	7-10	8 8
bony interorbital space	44	8-13	11	10	11	11	7-10	9 10
caudal peduncle depth	46	6-9	7	8	8	7	8-9	8 7
caudal peduncle length	46	13-18	15	15	14	15	13-19	17 16
snout 1.	46	9-13	13	10	13	11	8-12	9 10
head height	45	14-19	14	16	19	16	14-20	15 14
head width	45	19-28	22	22	25	22	19-23	21 20
internostril distance	25	7-12	9	9	10	8	6-15	- -
1. longest anal fin ray	40	12-28	17	12	17	12	13-19	16 14

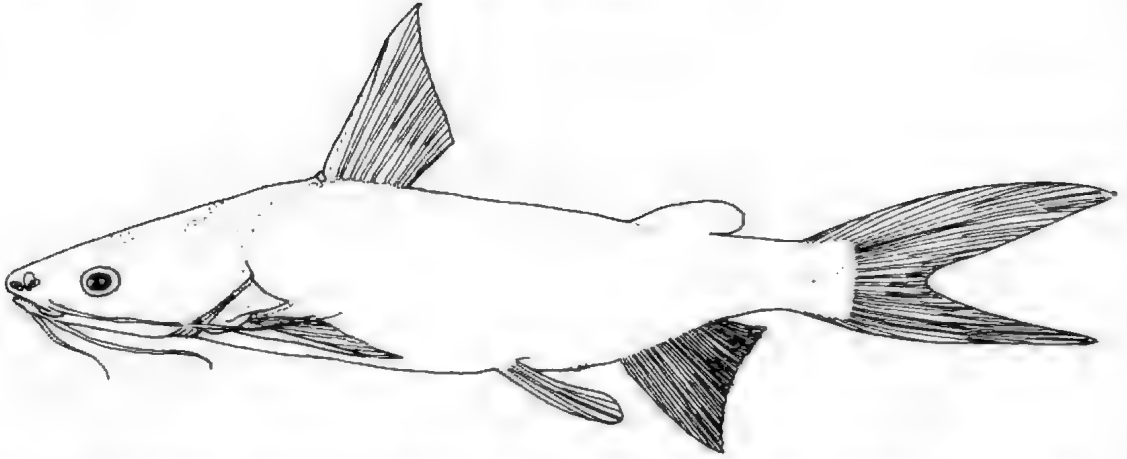


Fig. 1. Lateral view of *Arius graeffei*, 193 mm SL. AMNH field no. DR1969-94, 95: Hann R., W.A.

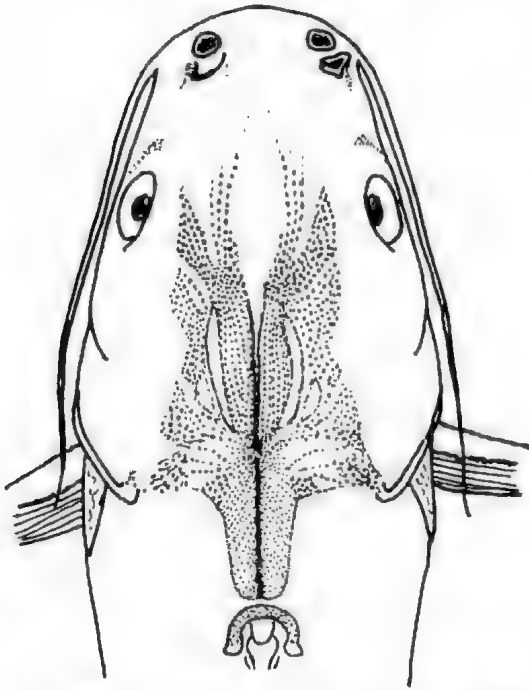


Fig. 2. Head view from above of *Arius graeffei*, 228 mm SL, SAM 4693, Clarence R., N.S.W.

from end of groove and laterally on head shield radiating from centres of small groups; interorbital flat, granulated head shield beginning above middle of eye; dorsomedian head groove narrow, straight-sided and moderately deep, originating above or slightly behind posterior margin of eye, terminating at base of occipital process. Sides of head smooth or slightly venulose. Median keel of occipital

process not prominent, process roughly triangular with straight sides, 1.0–2.1 (mean 1.4) longer than wide, its slightly rounded end contiguous with crescentic granular predorsal plate. In many specimens, noticeably those obtained from rivers, thick skin obscures head shield pattern. Humeral process rugose or with granulated striae, triangular and acute, horizontal or slightly oblique, extending one-third of the distance along pectoral fin spine length and ossified anteroventrally. Axillary pore present. Barbels thick, slightly flattened: maxillary barbels longest, extending at least to head edge, usually to above pectoral fin base or midway along fin spine; in juveniles (less than 130 mm SL) ending below dorsal fin spine; mandibular barbels may reach pectoral fin base; mental barbels reach about halfway between eye and pectoral fin base.

Rakers of first gill arch half as long as gill filaments; 12–20 (mean 16.7) short raker-like processes along back of first gill arch, 15–23 (mean 18.7) along back of second gill arch, 15–21 (mean 17.1) along back of third gill arch. Fleshy pad present on back of upper limb of each gill arch, that of second arch best developed.

Spines of dorsal and pectoral fins moderately thick with pattern of longitudinal striae, tips with short filaments; anterior margin of each spine rough with low denticles and 3–6 low antrorse serrae towards tip; posterior margin of dorsal spine smooth but low serrae towards tip in several specimens; posterior margin of pectoral spine dentate with 12–19 regularly-spaced stout sharp serrae. Longest dorsal ray 2.5–3.5 times length of last ray. Adipose dorsal

fin above middle of anal fin, its convex margin smooth; anal fin margin concave posteriorly, longest ray 2.4–3.3 times length of last ray. Ventral fin shape variable: in males, base narrow, fin rays rarely reaching anal fin origin—usually ending well before; in females, base broad, fin rays frequently reaching 4th–6th anal fin ray, inner (5th + 6th) elements of ventral fin becoming thickened and developing a pad or hook with sexual maturity. Caudal fin lobes moderate, pointed upper lobe slightly longer than lower lobe.

Caudal peduncle moderately thick, depth 1.6–2.6 (mean 2) in its length. Lateral line almost straight to tail base where it curves upward.

Fresh colour variable: dark brown, deep blue, fawn or dark ochre above (sometimes with iridescence), becoming yellowish, cream or white on undersides, sometimes brown-stippled over belly. Maxillary barbels black or dark brown, chin barbels either dark or pale; specimens from Victoria and Daly Rivers sometimes "piebald"—blotched black and white, black patches even extending into mouth and over fins (e.g. Victoria R. specimen AMS I.20857–001, 305 mm SL). Fins uniform tan or bluish, densely and finely stippled dark fawn to black, undersides of pectoral and ventral fins cream, base of anal fin and last few rays cream. Iris yellow. Peritoneum pale but faintly stippled dusky. In preservative the blue and iridescence are lost.



Fig. 3. The distribution of *Arius graeffei* (based on all material examined).

Distribution and Habitat (Fig. 3): Found from the Hunter River (N.S.W.) on the east coast, north and westward (Qld, N.T., W.A.) to as far south on the west coast as the Ashburton River and the Abrolhos Islands (AMS I.7035). Not common in New Guinea (Gulf of Papua coast, south-western New Guinea coast? Jamoer Lake). *Arius graeffei* is generally abundant in coastal draining rivers and streams from above tidal limits to estuaries and adjacent coastal waters.

Arius armiger De Vis 1884

FIGS 4, 5; Tables 1, 2.

Arius armiger De Vis 1884: 454 (New Britain—locality doubtful, probably northern Australia)

Arius stirlingi Ogilby 1898: 281 (estuary of Adelaide R., N.T.)

Material examined: Two syntypes of *A. armiger*: QM I.3089, unknown locality, 134 mm SL and QM I.3088, unknown locality, 148 mm SL; and 28 additional specimens from the following localities: Qld: 1, QM I.867, "Queensland coast", 215 mm SL; 1, AMNH 17717, same data, 178 mm SL; 3, Moonkan R., 259–285 mm SL; 2, QM I.11789, Kurumba, 105 and 111 mm SL; 2, CSIRO C.3800 and C.4378, Norman R. at Kurumba, 161 and 188 mm SL; 2, QM I.11632, Rynoe R., 79 and 89 mm SL; N.T.: 2, SAM F.1094 and F.1095, Adelaide R., 221 and 280 mm SL; 2, Murganella Creek, 102 and 111 mm SL; 1, East Alligator R. mouth, 74 mm SL; 1, AMNH unreg., Victoria R., 87 mm SL; W.A.: 5, King R. near Wyndham, 174–265 mm SL; New Guinea: 1, Mojanamu, Papua, 129 mm SL; 1, Kubiri Creek, Papua, 160 mm SL; 2, Baimuru, Papua, 142 and 257 mm SL; 1, CSIRO A.3043, Kerema Bay, Papua, 93 mm SL; 1, Kerema, Papua, 155 mm SL.

Definition: distinguished by combination of: absence of raker-like processes from back of first and usually second gill arches; palatal teeth small and sharp and in transverse series of four oval patches; dorsal fin spine noticeably longer than pectoral fin spine; maxillary barbels reaching dorsal fin at least; anal fin with 22–25 elements.

Description (based on 30 specimens): D.I.7: A.22–25 (mean 24); P.I.9–10; GR (first arch) 16–22, mean 19 (total) of which 7–8 on upper limb; GR (last arch) 16–22, mean 18.6 (total); C. primary rays 7 + 8; V.6; number of free vertebrae 43–45.

Body slender, elongate (Fig. 4, Table 1, 2); anterior profile straight to occipital process base whence distinctly convex; mouth moderately broad and slightly curved, its width 2–2.3 (mean 2.1) in head length, upper jaw evenly curved, symphysis of lower jaw slightly but distinctly elevated; snout rounded, mode-

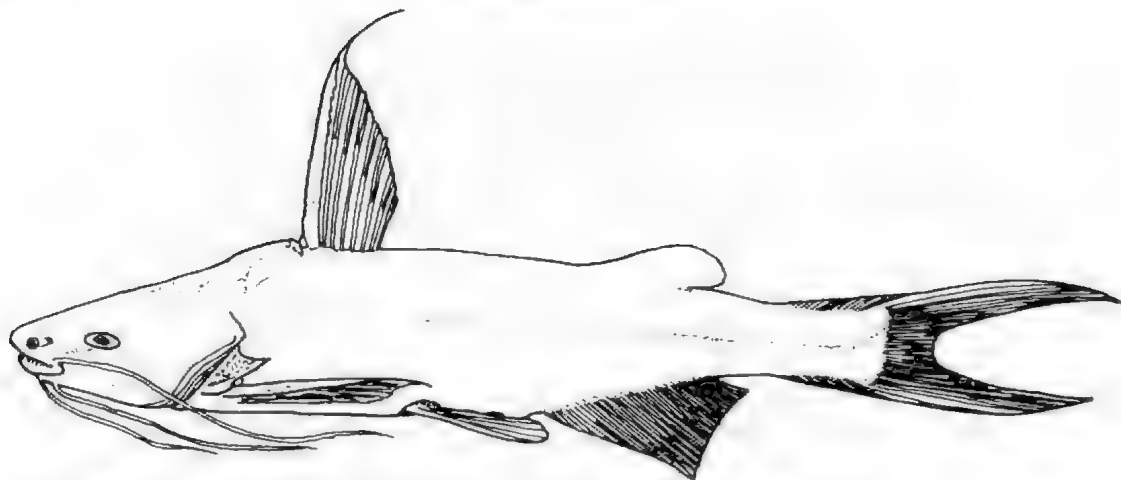


Fig. 4. Lateral view of *Arius armiger*, 161 mm SL CSIRO C3800: Norman R., Qld.

rately thickened lips extending slightly beyond mouth gape such that $\frac{1}{2}$ –1 maxillary tooth band exposed when mouth closed; no (or rarely) shallow groove on snout; hind nostril ovate-elliptical, low frills laterally; anterior flap barely concealing opening; eye ovate-oblong, dorso-lateral, orbit noticeably oblique; eye only free of orbit antero-ventrally and positioned $1\frac{1}{2}$ an eye diameter before mid-length of head.

Jaw teeth in curved bands, villiform: slender and sharp, depressible and in 5–9 series; breadth of maxillary tooth band 4.3–10.6 (mean 8.3) in its length; narrow edentulous space separates each side of mandibular tooth band. Four patches of low, sharp and stout or bluntly-pointed conical teeth on palate arranged transversely: vomerine patches rounded, always well separated at midline; outer palatine patches larger and elongate-oval, contiguous or adjacent to vomerine patches. Short angular skin flap well back on smooth palate.

Head shield (Fig. 5) smooth anteriorly, posteriorly and laterally feebly granulated; striate ridges posteriorly each side of dorso-median head groove; sides of head and snout smooth and venulose; head shield beginning before eye; interorbital flat or slightly concave; dorsomedian head groove narrowly elliptical and moderately deep, originating slightly behind posterior eye margin and terminating at base of occipital process. Finely granulated striae radiate in parallel series over occipital process from its base, median keel sharp and strong, process 1.1–1.9 (mean 1.5) longer than wide, sides slightly concave, hindborder emarginate or indented, contiguous with cres-

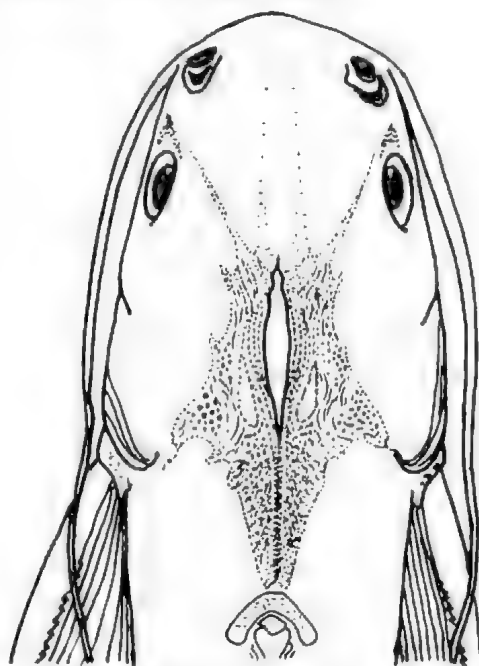


Fig. 5. Head view from above of *Arius armiger*, 188 mm SL, CSIRO C4378: Norman R., Qld

centic predorsal plate. Humeral process smooth or rugose, triangular and short, lower border concave, heavily ossified antero-ventrally; process horizontal or slightly oblique, extending $\frac{1}{2}$ distance along pectoral fin spine length. Axillary pore moderately large. Barbels slender, flattened: maxillary barbels longest, always reaching dorsal fin and often as far as ventral fin origin; mandibular barbels reach opposite occipital process or to below mid-dorsal fin; mental barbels usually extend past gill opening to base of pectoral fin.

Rakers of first gill arch two-thirds length of gill filaments; back of first arch smooth; back of second arch often smooth, otherwise with 1-4 small raker-like processes on upper limb; 16-21 (mean 18.6) moderate processes along back of third arch. Thickening of upper limb of each gill arch developed as fleshy pad on second limb. Spines of dorsal and pectoral fins slender, almost smooth, tips with filaments—that of dorsal spine noticeably long; anterior margin of dorsal spine roughened, even granular, of pectoral spine almost smooth; 5-9 low antrorse serrae towards tip of each spine; posterior margin of dorsal spine with 14-19 low sharp serrae, posterior margin of pectoral spine with 17-22 regularly-spaced stout strong serrae. Longest dorsal fin ray 2.9-4.1 times length of last ray. Adipose fin above middle of anal fin, margin smooth, truncate or slightly convex; anal fin margin straight or slightly emarginate posteriorly, longest ray 2.3-3.6 times length of last ray. Ventral fin shape variable: in males, base narrow, fin rays rarely reaching anal fin origin; in females, base broad, fin rays reaching opposite 3rd-8th anal fin ray, inner (5th + 6th) elements becoming thickened and developing a fleshy pad with sexual maturity. Caudal fin lobes slender, tapered, upper lobe slightly longer than lower.

Caudal peduncle compressed, depth 1.5-2.4 (mean 1.9) in its length. Lateral line much branched, especially anteriorly, line almost straight to tail base where it curves upward.

Fresh colour. Readily recognisable by its coppery or golden brown or bronze head and upper sides, shading to creamy yellow below. Fins coppery-fawn or dusky yellow, pale orange basally and finely stippled grey, margins and filaments charcoal, undersides of pectoral and ventral fins cream; iris coppery; all barbels dark brown. Peritoneum pale grey or white. Carter (*in litt.* Jan. 1981) noted fresh colouration of three mature female specimens from the Moonkan River as very pale greyish-pink dorsally, creamy below; fins slightly pink and broadly edged black; ventral fins creamy white. In preservative, the pink, orange and sheen are lost.

Distribution and Habitat (Fig. 6): In Australia found from Edward River system, Cape York westward along the Gulf of Carpentaria, Northern Territory and as far as the King River (W.A.); in New Guinea from Yule Island to the Digoel (Hardenberg, 1941) and Lorentz (Weber, 1913) Rivers in the west.



Fig. 6. The distribution of *Arius armiger* (based on all material examined and authentic literature records).

Arius armiger is abundant in shallow coastal waters and lower estuarine zones, not extending into fresh water.

Discussion

A. Arius graeffei

Arius graeffei was described in a paper by Kner & Steindachner read before a meeting of the Austrian Academy of Sciences on 5th July 1866 and published that year in the Society's "Sitzungsberichte" (vol. 54). The specimen, from "Samoa Inseln", was subnumbered 2103 in the Godeffroy Museum collection.

On 24th January 1867, Günther read before the Zoological Society of London a paper in which he described *Arius australis* based on three specimens sent to the British Museum by Krefft from Ash Island in the Hunter River, N.S.W. These syntypes are catalogued BMNH 1866.2.13:4 (275 mm SL), 1866.6.19:7 (380 mm SL) and 1866.6.19:8 (300 mm SL).

Günther (1909) presents the figures and an abbreviated description of Kner & Steindachner's *Arius graeffei* from "Samoa". Günther did not view the specimen and perhaps the wide geographical discrepancy of stated type locality led him not to remark how similar was *A. graeffei* to his own species *A. australis*.

In the Australo-papuan region *A. graeffei* was first mentioned by Paradise & Whitley (1927) who stated "the only species of marine catfish met with" in the Sir Edward Pellew Island Group (15°40'S, 136°30'E) was *Arius* (*Tachysurus*) *graeffei* Kner & Steindachner, considered "A new record for Australia" (p. 80). They also (p. 97) suggested that Kner &

Steindachner meant "East Indies" instead of "Samoa" as the type locality.

I have examined a 245 mm SL specimen presented to the Australian Museum by Paradise in 1923 from the Pellew Group (and likely to be the specimen he and Whitley identified as *A. graeffei*). Labelled *Arius* (*Tachysurus*) *graeffei* (AMS 1A.1484) it is actually an example of *Arius proximus* Ogilby 1898.

Paradise & Whitley's record of *A. graeffei* non Kner & Steindachner may have led McCulloch (1929: 59) to include *A. graeffei* Kner & Steindachner in his checklist of Australian fishes, stating "Samoa (locality doubtful). North Australia, Indo-Pacific?". Whitley (1940) realised that the Pellew Island specimen was *A. proximus*, listing it in the synonymy of that species. He also questionably considered *A. proximus* Ogilby a junior synonym of *A. graeffei* Kner & Steindachner. Later however (1941) he listed *A. graeffei*, *A. proximus* and *A. australis* as valid Australian species. Taylor (1964), although apparently unaware of Whitley's 1940 correction, arrived at the same conclusion and questionably referred Paradise & Whitley's *A. graeffei* to *A. proximus* Ogilby, but did not list *A. graeffei* as a valid Australian species.

Kner & Steindachner likened *Arius graeffei* to *Arius gagorides* (Valenciennes, 1840). Fowler (1928: 61) went even further, stating: "in its roughly granular head and spines, and especially the dentition, it approaches *Pimelodus sona* Buchanan-Hamilton" [sic] and immediately placed *A. graeffei* as a junior synonym of *Tachysurus sona* (Buchanan-Hamilton, 1822) [sic] type locality estuaries of Bengal. Weber & de Beaufort (1913) and Chandy (1953) regarded *A. gagorides* questionably valid; Misra (1976) appears to follow Fowler who again (1941) placed as synonyms: *A. sona* (Buchanan-Hamilton, 1822) [sic], *A. gagorides* (Val. 1829) [sic], *A. trachipomus* Val. 1839 and *A. graeffei* Kner & Steindachner. McKay (QM) recently examined the type specimens of *A. gagorides* and *A. trachipomus* on my behalf and found that they are synonyms of *A. sona*, and that *A. graeffei* is a distinctly different species.

Macleay (1881) recorded *Arius gagorides* from Port Darwin, his description mostly copied from Günther (1864). Macleay's specimen became the holotype of *Arius mastersi* Ogilby 1898 (MMUS F.153). Interestingly,

Ogilby (1898a) considered *A. gagorides* and *A. sona* conspecific (i.e. predating Fowler).

In Australian literature, the name *A. graeffei* appears only once more: as *Pararius graeffei* (Whitley, 1964).

Kner & Steindachner's specimen of *A. graeffei* was located in the Naturhistorisches Museum, Vienna (NMW 67.152) and I have compared it with similar-sized specimens of *A. australis* Günther from Australia. The *A. graeffei* holotype is in reasonably good condition, and judged by the length and condition of the ventral fins, is a female.

Ahnelt (NMW) (*in litt.*) says that large sections of the Godeffroy collection were sold last century and further, that it is not uncommon for Godeffroy fishes to have incorrect locality data. Kner & Steindachner (1866) described fishes not included in the earlier works by Grasse on material in the Godeffroy collection. Although most of the collection came from Fiji, Samoa and the Phoenix Islands there is every reason to believe that the 252 mm SL specimen of *A. graeffei* did not, and was one of a miscellaneous group of natural history specimens presented to the Museum by a now untraceable donor. *Arius graeffei* is thus a senior synonym of *A. australis* Günther 1867.

Arius curtisii Castelnau 1878 is also a junior synonym of *A. graeffei*. I have examined a syntype (MNHN B.693, 144 mm SL) which is in poor condition. Castelnau stated (1878: 237) "I have several specimens, but all badly preserved; the largest is nearly fifteen inches long, the others are about six inches." The type locality is Moreton Bay. It has not been possible to locate the remaining Castelnau specimens.

B. *Arius armiger*

The type locality of *Arius armiger* De Vis 1884 is stated to be New Britain (Bismarck Archipelago, New Guinea). Doubts about the validity of this type locality arose because: (1) *Arius armiger* has remained (until now) known only from the types; (2) there are no subsequent records of catfishes from New Britain despite extensive fishery surveys around the island during the past 12 years by the Papua New Guinea Fisheries Research & Survey Division; (3) New Britain, a mainly mountainous island, has short, fast-flowing rivers which do not form extensive estuaries; (4) no fishes of the family Ariidae have been recorded east of the main New Guinea island.

The type specimens of *Arius armiger* De Vis at the Queensland Museum (L3089, 134 mm SL and L3088, 148 mm SL) on examination proved to be specimens of the common Papuan and northern Australian estuarine catfish *Arius stirlingi* Ogilby 1898, which therefore becomes a junior synonym of *A. armiger* De Vis 1884.

De Vis (1884) states: "To Government agents and captains employed in hiring hands for the plantations, I am indebted for several opportunities of examining fish from the prolific waters around the Islands from which the labour supply is derived. In the collections thus incidentally made . . ." (p. 445). The fishes described in this paper were reportedly collected from New Hebrides, South Seas, "probably South Seas", Duke of York's Group, Bank's Group, Api and New Ireland. It is probable that specimen information on the "incidental collections" made was occasionally confused, hence the type locality of New Britain for *A. armiger*.

Unsuccessful attempts were made to obtain records of the voyages from which De Vis obtained specimens. Even so, it seems likely that the *A. armiger* types were collected on the north Queensland coast or the Papuan coast on an outward or return voyage.

A search was made for the single type specimen of *A. stirlingi* Ogilby, although Roberts (1978) had been unable to trace it in the Queensland and Australian Museums. The specimen is not in the National Museum, Victoria (Gomon, *in litt.*, 1981) and I could not find it in the collection of the Macleay Museum and of the South Australian Museum. Ogilby stated (1898b) that his 270 mm long specimen of *A. stirlingi* was one of a small collection of fishes sent to him by the South Australian Museum authorities from the estuary of the Adelaide River, N.T. There are

two specimens of *A. armiger* in the S.A. Museum from the Adelaide River collected in 1928. One (P.1094) is 221 mm SL, 265 mm TL; the other (P.1095) is 281 mm SL, 359 mm TL.

In 1908, Ogilby proposed a new genus *Nemapteryx*, to accommodate *Arius stirlingi*. However this allocation is not supported by my studies, and I conclude that *A. stirlingi* is a junior synonym of *A. armiger*.

Indicative of the disinterest in these fishes is the fact that *A. armiger* (as *Nemapteryx stirlingi*) was recorded from Papua only 19 years ago (Munro, 1964).

Acknowledgments

In my search for information many people have generously given their assistance. I am indebted to Marie-Louise Bauchot (MNHN), Alwynne Wheeler (BMNH), Rainer Hacker and H. Ahnelt (NMW), the secretary of the Zoological Society of London, of the Austrian Academy of Science, of the Linnean Society of New South Wales, John Glover (SAM), Janet Gomon (USNM), Martin Gomon (NMV), Rolly McKay (QM), Han Nijssen (ZMA) and MMUS staff. For their assistance in sending me specimens, both from institutions and especially obtained on my behalf. I wish to thank Hamar and Mary Midgley, Darryl Grey, Rolly McKay, Noel Morrissey, Alan Haines, Mike Rimmer, Keith Bishop and Sally Allen, Bill Rooney, Dave Carter, Lee Turner, Tim Davis, Marinus Boeseman and M. J. P. van Oijen, John Paxton, Ian Munro, Barry Hutchins, and especially Norma Feinberg (AMNH). Rolly McKay has been particularly helpful in supplying specimen information and constructive manuscript criticism. Finally thanks are due to my husband and son for their patience and to Michael J. Tyler (supervisor, University of Adelaide).

References

- CASTERNALL, F. L. (1878) Australian fishes. New or little known species. *Proc. Linn. Soc. N.S.W.* 2(3), 225-248.
- CHANDY, M. (1953) A key for the identification of the catfishes of the genus *Tachysurus* Lacépède, with a catalogue of the specimens in the collection of the Indian Museum (Zool. Surv.), *Rec. Indian Mus.* 5L, 1-18, 3 pls.
- DE VIS, C. W. (1884) Fishes from South Sea Islands, *Proc. Linn. Soc. N.S.W.* 8, 445-457.
- FOWLER, H. W. (1928) The fishes of Oceania. *Mem. Bernice P. Bishop Mus.* 10, 312, 540 pp.
- (1941) Contributions to the biology of the Philippine Archipelago and adjacent regions. *Bull. U.S. natn. Mus.* 100, v.13, x, 879 pp.
- GRANT, E. M. (1978) *Guide to fishes*. Dept Primary Industry, Brisbane, 768 pp, 4th edition.
- GÜNTHER, A. (1864) *Catalogue of the fishes in the British Museum*. Volume 5, xlii, 455 pp.
- (1867) Descriptions of some new or little-known species of fishes in the collection of the British Museum. *Proc. Zool. Soc. Lond.*, 99-104.
- (1909) Andrew Garrett's Fische der Südsee. *J. Mus. Godesberg*, 8(16), 261-388.
- HARDENBERG, J. D. F. (1941) Fishes of New Guinea. *Treubia* 18(2), 217-231.

- HUBBS, C. L. & LAGLER, K. G. (1958) Fishes of the Great Lakes Region. *Bull. Cranbrook Inst. Sci.* **26**, xi, 213 pp.
- KNER, R. & STEINDACHNER, F. (1866) Neue fische aus dem Museum der Herren Joh. C. Godeffroy und Sohn in Hamburg. *Sitzb. Akad. Wiss. Wien*, **54**(1), 356-395.
- LAKE, J. S. (1971) *Freshwater fishes and rivers of Australia*. (Nelson: Melbourne) 61 pp.
- & MIDGLEY, S. H. (1970) Reproduction of freshwater Ariidae in Australia. *Aust. J. Sci.* **32**(11), 441.
- MACLEAY, W. (1881) Descriptive catalogue of the fishes of Australia. *Proc. Linn. Soc. N.S.W.* **6**(2), 202-387.
- MCCULLOCH, A. R. (1929) A check-list of the fishes recorded from Australia. *Mem. Aust. Mus.* **5**(1), 1-144.
- MISRA, K. S. (1976) *The fauna of India and adjacent countries. Pisces* (second edition) vol. III, Teleostomi: Cypriniformes; Siluri. Government of India, pp. xxi, 367, pls I-XV.
- MUNRO, I. S. R. (1957) Handbook of Australian fishes, no. 9, pp. 37-40. *Fish. Newsl.* **16**(3), 15-18.
- (1964) Additions to the fish fauna of New Guinea. *Papua New Guin. agric. J.* **16**(4), 141-186.
- OGILBY, J. D. (1898a) New genera and species of fishes. *Proc. Linn. Soc. N.S.W.* **23**(1), 32-41.
- (1898b) New genera and species of fishes. *Ibid.* **23**(3), 280-299.
- (1908) New or little known fishes in the Queensland Museum. *Ann. Qd Mus.* **9**(1), 1-38.
- PARADICE, W. E. J. & WHITLEY, G. P. (1927) Northern Territory fishes. *Mem. Qd Mus.* **9**(1), 76-106.
- POLLARD, D. A. (1974) *The freshwater fishes of the Alligator River, "Uranium Province" area (Top End, N.T.) with particular reference to the Magela Creek catchment (East Alligator River System)*. Australian Atomic Energy Commission, 77 pp.
- (1980) Family Ariidae. Estuarine Salmon or Fork-tailed Catfishes. In R. M. McDowall (ed.), *Freshwater Fishes of South-eastern Australia*. (Reed: Sydney) pp. 89-90.
- ROBERTS, T. R. (1978) An ichthyological survey of the Fly River in Papua New Guinea with descriptions of new species. *Smithsonian Contrib. Zool.* **281**, vi, 72 pp.
- TAYLOR, W. R. (1964) Fishes of Arnhem Land. *Rec. Amer. Aust. Sci. Exped. Arnhem Land* **4**, 45-307.
- WEBER, M. (1913) *Nova Guinea. Résultats de l'Expedition Scientifique Néerlandaise à la Nouvelle-Guinée en 1907 et 1909 sous les auspices de Dr H. A. Lorentz*. Vol. IX Zoologie, livraison IV. (E. J. Brill: Leiden) pp. 513-613.
- & DE BEAUFORT, L. F. (1913) *The Fishes of the Indo-Australian Archipelago*, Vol. 2. (E. J. Brill: Leiden) 404 pp.
- WHITLEY, G. P. (1940) Illustrations of some Australian fishes. *Aust. Zool.* **9**(4), 397-428.
- (1941) Ichthyological notes and illustrations. *Ibid.* **10**(1), 1-50.
- (1964) Presidential address. A survey of Australian ichthyology. *Proc. Linn. Soc. N.S.W.* **89**(1), 11-127.

TRANSACTIONS OF THE
ROYAL SOCIETY
OF SOUTH AUSTRALIA
INCORPORATED

VOL. 107, PART 4

DEVELOPMENT OF LITORIA INFRAFRENATA (ANURA: HYLIDAE)

BY C. B. BANKS, J. R. BIRKETT, R. W. DUNN & A. A. MARTIN

Summary

The developmental pattern and larval morphology of *Litoria infrafronata* are typical of Australopapuan hylid frogs. The larvae have a spectacular colour pattern and the larval life-span is 58 days at 24-28°C. Some data on post-metamorphic growth are provided.

DEVELOPMENT OF *LITORIA INFRAFRENATA* (ANURA: HYLIDAE)

by C. B. BANKS*, J. R. BIRKETT[†], R. W. DUNN[‡] & A. A. MARTIN[‡]

Summary

BANKS, C. B., BIRKETT, J. R., DUNN, R. W. & MARTIN, A. A. (1983) Development of *Litoria infrafronata* (Anura: Hylidae). *Trans. R. Soc. S. Aust.* **107**(4), 197-200, 30 November, 1983.

The developmental pattern and larval morphology of *Litoria infrafronata* are typical of Australopapuan hylid frogs. The larvae have a spectacular colour pattern and the larval life-span is 58 days at 24-28°C. Some data on post-metamorphic growth are provided.

KEY WORDS: Anura, Hylidae, *Litoria*, Development, Larvae.

Introduction

Litoria infrafronata (Günther), the Giant Green Tree Frog, is the largest Australopapuan hylid, and one of the largest tree-frogs in the world, with an adult body length of up to 135 mm (Tyler & Davies 1978). It is widely distributed in the Papuan region, ranging from eastern Indonesia through mainland New Guinea to the Bismarck, Admiralty and Louisiade Islands; and also occurs in northern Queensland (Menzies 1976). Two subspecies are recognized (Tyler & Davies 1978): *L. i. militaria* is restricted to the Bismarck Archipelago; the Queensland population from which our data were gathered represents the nominate subspecies. General information on the distribution and biology of *L. infrafronata* is given by Menzies (1976); variation in cranial osteology has been described by Davies (1978); the unusual karyotype ($n = 12$; in all other Australian hylids $n = 13$) is discussed by Menzies & Tippet (1976); and larval morphology is briefly described by van Kampen (1923).

We have taken the opportunity provided by a captive breeding of *L. infrafronata* in the Melbourne Zoo to make some observations on the development of this species. As well as contributing to the presently limited knowledge of this distinctive frog, our studies also provide further comparative data on the life histories of Australian hylids, recently reviewed by Watson & Martin (1979).

Materials and Methods

Stocks of adult *L. infrafronata* in the Zoo were acquired from produce markets, having

arrived in Melbourne in crates of fruit from northern Queensland. Three females of snout-vent lengths 90, 100 and 113 mm arrived between 1977 and 1980; a male of 101 mm snout-vent length arrived in May 1981. He was initially housed separately from the females; on 9 September 1981 he was heard to call and was placed with the females. The group was housed in a 2 m \times 2 m \times 1.8 m display enclosure also containing Scrub and Carpet Pythons, which included living plants and a pond measuring some 1 m \times 0.8 m, 0.3 m deep. The enclosure was naturally lit, with lighting supplemented by a 1.2 m "True-Lite" fluorescent tube which was switched on daily between 0810 and 1650 hours. Air temperature in the display varied between about 24 and 30°C, occasionally reaching 35°C at the top of the enclosure. The frogs were fed on locusts, crickets and chopped mice. The male continued to call intermittently and amplexus was observed on 6 December 1981. Embryos were found in the pond on 9 December; water temperature was 22.5°C.

The embryos were removed from the pond and divided among three 600 \times 300 \times 300 mm aquaria containing water to a depth of 200 mm. Water temperature varied between 24 and 28°C. Larvae were fed on chopped endive; a few larvae were preserved in 4% formalin at intervals for later examination. On 11 January 1982 a small sample was anaesthetized with MS-222 (Sandoz) for microscopic study of the pigmentation pattern in life. As the tadpoles approached metamorphosis shelving rocks were provided for their emergence. Froglets were reared in a variety of terraria under various conditions of lighting and temperature, and were fed on houseflies.

Measurements of developmental stages were made using vernier calipers reading to 0.1 mm. The embryo and larval mouth disc were drawn

* Reptile Department, Royal Melbourne Zoological Gardens, P.O. Box 74, Parkville, Vic. 3052.

[†] Department of Zoology, University of Melbourne, Parkville, Vic. 3052.

under a stereoscopic microscope; the larval drawings were traced from projections of 35 mm colour transparencies. Developmental stages were classified by the system of Gosner (1960).

Results

Breeding behaviour: The male called at intervals through September and October. Calling was usually heard in the mornings, and often followed disturbance, e.g. the introduction of live food, or spraying the exhibit with water. We were unable to obtain recordings of the call; Menzies (1976) describes it as a loud, double bark, produced while males are perched in trees 3–4 m above the ground, or floating in the water. Preferred breeding sites are deep, shaded swamps in forested areas.

Amplexus is axillary; on 6 December 1981 the male entered amplexus with the largest female, and the embrace continued from 0800 to at least 1030 hours. It took place on a *Phyllodendron* root at the pond surface.

Eggs: Oviposition was not observed; in fact we did not realize that breeding had occurred until embryos were found in the pond on 9 December. At this time a number of infertile eggs was also found; these were adhering to the sides of the pond. The eggs had a heavy fungus infection but it could be ascertained that they were pigmented and had a diameter of about 1.9 mm. Egg capsules were discrete and had a diameter of about 3.6 mm. Approximately 180 infertile and 250 fertile eggs were laid, giving a total clutch size of about 430.

Embryos: Dimensions of embryos and larvae are shown in Table 1. Only one series of embryos, in Stage 22, was preserved on 9 December, just after they had hatched. Their general colour was dark brown and their

total length about 6.2 mm. The cornea was clear and the external gills were very prominent (Fig. 1A). There were six long filaments in the anterior group on each side, and three much shorter ones in the posterior group.

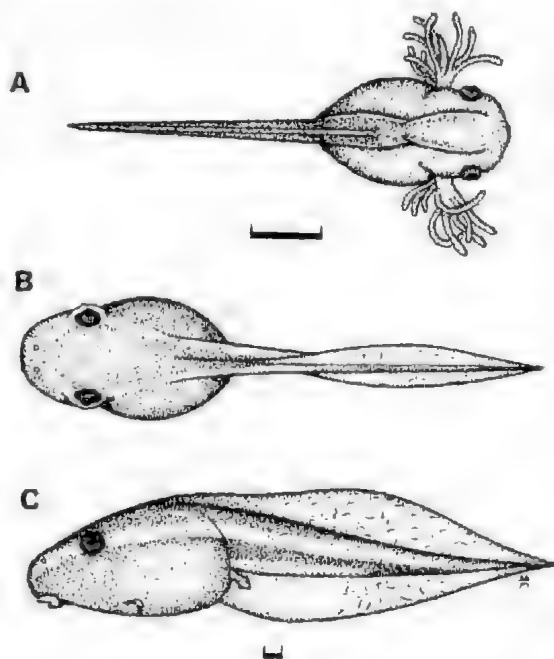


Fig. 1. Developmental stages of *Litoria infra-frenata*. A, Stage 22 (newly hatched); B and C, Stage 31. The bar in each case represents 1 mm.

Larvae: On 11 December the larvae were in Stage 25, and had a total length of 8.6–8.8 mm. The spiracle and mouth disc were fully formed, and the ventral suckers remained only as pigment-free patches. The general colour was dark brown. For most of the time the larvae floated in mid-water in a tilted, head-up attitude.

By 13 December the larvae had begun to graze on algae on the sides and floors of the tanks and on the chopped endive that was provided. They were in Stage 25, with a total length of 10.9–11.2 mm. Lateral stripes had begun to develop: a creamy-white stripe ran through the naris and eye, along the body, and down the dorsal half of the tail musculature. The ventral edge of the tail musculature was also creamy-white; elsewhere the colour was dark brown.

Two larvae preserved on 15 December were in Stage 26, and had total lengths of 12.3 and

TABLE 1. Dimensions of developmental stages of *Litoria infra-frenata*. Values are means of 2–3 individuals.

Age (days)	Stage	Body length (mm)	Total length (mm)
3	22	—	6.2
5	25	3.8	8.7
7	25	4.5	11.1
9	26	5.3	13.7
16	28	7.5	17.8
23	30	9.7	25.4
30	31	13.6	37.4
37	37	16.4	44.9
44	42	18.6	53.5
51	44	22.6	38.9
58	46	22.4	—

15.0 mm. From this time on considerable variations in larval growth rate became apparent, with the largest larvae being up to 50% bigger than the smallest ones. On 22 December the larvae were in Stage 28, with total lengths of large larvae reaching 17.8 mm; on 29 December the larvae were in Stage 30, and measured up to 25.4 mm in total length.

A larva preserved on 5 January 1982 is illustrated in Figs. 1B and 1C; it is in Stage 31, with a total length of 37.4 mm. The anus was dextral and the spiracle low on the left side of the body. The dorsal fin was well-arched and the tail tapered to a slender, acuminate tip. In life at this stage the general body colour was dark brown. The lateral stripes had become brilliant silvery-orange, with no melanophores but large numbers of golden chromatophores. The ventrolateral and ventral abdominal surfaces were silvery-yellow, with a fine dusting of brown pigment. The dorsal and ventral fins were dusky brown in the anterior two-thirds, and clear in the posterior third.

The mouth disc of a larva in Stage 31 is shown in Fig. 2. There are two upper and

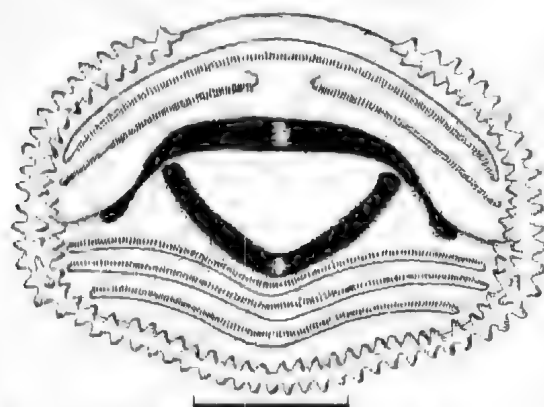


Fig. 2. Mouth disc of Stage 31 larva of *Litoria infrafrenata*. The bar represents 1 mm.

three lower rows of labial teeth, with only the second upper row having a median gap. A narrow band of papillae surrounds the lateral and posterior margins of the disc.

On 12 January two larvae were in Stage 37, and had total lengths of 42.7 and 47.1 mm. The largest larva in the series was preserved in Stage 42 on 19 January, and had a total length of 53.5 mm.

Metamorphosis: By 26 January the body colour of the larvae had become grass-green, and the larvae were beginning to climb the sides of the aquaria. Two larvae in Stage 44 had body lengths of 22.4 and 22.8 mm, with tail stubs of 18.6 and 13.9 mm. By 1 February all 163 surviving larvae had completed metamorphosis; two of them had snout-vent lengths of 21.6 and 23.2 mm. Houseflies were provided on 28 January and the froglets began to feed immediately; cannibalism of smaller by larger froglets was subsequently noted.

Larval life-span: Assuming that the eggs were laid on 6 December, the larval life-span extends over 58 days at 24–28°C.

Post-metamorphic growth: Froglets were weighed and measured at monthly intervals after the completion of metamorphosis (Table 2). After 7 months the froglets were divided into two groups, one of which was reared in the reptile house (RH) and the other in the Zoo education area (EA). For a reason which is not clear the froglets in the latter group grew considerably faster than those in the former.

On 9 March 1983 an EA specimen began to extrude eggs while being handled. A total of about 480 eggs was laid. Hence for this female sexual maturity was attained at an age of 402 days (after metamorphosis) and a snout-vent length of 77 mm.

Mortality of froglets: In June 1982 some of the froglets began to show a syndrome which first presented as oedema in the cloacal region; later they became lethargic and emaciated,

TABLE 2. Post metamorphic growth of *Litoria infrafrenata*. Up to 7 months values are means of 3–5 specimens. After 7 months there were two specimens in the reptile house (RH) and two in the education area (EA); one of the EA specimens died after the 9th month.

	Months after completion of metamorphosis											
	1	2	3	4	5	6	7	8	9	10	11	12
Body weight, g	1.6	3.2	4.2	4.6	5.4	7.3	7.6	RH 13.5	14.8	15.1	18.2	22.5
								EA 15.0	23.9	27.9	28.4	35.5
Snout-vent length, mm	26	33	40	42	44	47	49	RH 56	57	59	62	65
								EA 66	71	74	75	76

and tended to lose coordination of the hind limbs. In all 29 froglets died between June and November following the appearance of these symptoms. Various treatments with chloramine (Halamid; Cenvet), oxytetracycline hydrochloride (Engemycin; Philips Dufar) and neomycin sulphate (Neobiotic; Tuco) were attempted, and adjustments of temperature and humidity were also made, but no treatments appeared to be effective. Autopsy did not reveal either the presence of pathogens or the likely cause of death.

Discussion

Martin & Watson (1971) noted that the general patterns of life history of Australian hylids are remarkably uniform. Most Australian species of *Litoria* lay small, pigmented eggs in water; egg-clumps are typically attached to submerged objects. The presence of two pairs of embryonic external gills is also typical. Larval morphology is somewhat more variable, with some species (e.g. *L. lesueuri*; Martin & Watson 1971) showing lotic adaptation of the mouth structure and general body form. More usually, however, Australian hylid larvae are of the high-finned, actively-swimming nektonic type, well exem-

plified by *L. infrafrenata*. The dorsolateral eye position, ventrolateral spiracle and acuminate tail-tip are also typical hylid features. The mouth disc is unusual in having the first lower row of labial teeth entire; more usually it has a median gap.

The lateral stripe of the larva is one of its most prominent features; we presume that it may be the fore-runner of the equally conspicuous labial stripe of the adult.

The larval life-span of 58 days recorded here is probably not unusually fast among tropical species. Watson & Martin (1979) recorded a larval life-span at 27°C of 41 days for *L. chloris*, a northern Australian rainforest green tree-frog. On the other hand the interval of approximately 13 months between metamorphosis and sexual maturity does seem surprisingly short for such a large frog, but data on the age at which maturity is attained in anurans are extremely sparse (e.g. Flower 1936).

Acknowledgments

We thank Helen Madder for help with rearing froglets, and Graeme Watson for commenting on the manuscript.

References

- DAVIES, M. (1978) Variation in the cranial osteology of the Australo-Papuan hylid frog *Litoria infrafrenata*. *Rec. S. Aust. Mus.* **17**, 337-345.
- FLOWER, S. S. (1936) Further notes on the duration of life in animals—II. Amphibians. *Proc. Zool. Soc., Lond.* **1936**, 369-394.
- GOSNER, K. L. (1960) A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* **16**, 183-190.
- MARTIN, A. A. & WATSON, G. F. (1971) Life history as an aid to generic delimitation in the family Hylidae. *Copeia* (1971) 78-89.
- MENZIES, J. I. (1976) "Handbook of Common New Guinea Frogs" (Handbook No. 1, Wau Ecology Institute; Papua New Guinea).
- & TIPPETT, J. (1976) Chromosome numbers of Papuan hylid frogs and the karyotype of *Litoria infrafrenata* (Amphibia, Anura, Hylidae). *J. Herpetol.* **10**, 167-173.
- TYLER, M. J. & DAVIES, M. (1978) Species-groups within the Australopapuan hylid frog genus *Litoria* Tschudi. *Aust. J. Zool., Suppl. Ser. No.* **63**.
- VAN KAMPEN, P. N. (1923) "Amphibia of the Indo-Australian Archipelago" (Brill: Leiden).
- WATSON, G. F. & MARTIN, A. A. (1979) Early development of the Australian green hylid frogs *Litoria chloris*, *L. fullax* and *L. gracilentia*. *Aust. Zool.* **20**, 259-268.

THE DUMONTIACEAE (CRYPTONEMIALES: RHODOPHYTA) OF SOUTHERN AUSTRALIA

BY E. ANN SHEPLEY & H. B. S. WOMERSLEY

Summary

Four genera and species of Dumontiaceae are known from southern Australian seas. *Dasyphloea insignis* Montagne occurs from Wanna, S. Aust., to Waratah Bay, Vic., and around Tasmania; *Dudresnaya australis* J. Agardh from King Georges Sound, W. Aust., to Western Port, Vic., and the north coast of Tasmania; and a single collection from the Isles of St Francis, S. Aust., is referred to *Acrosymphyton taylorii*, previously known from the Hawaiian Islands. The reproduction of these species is described in detail. A new genus and species, *Kraftia dichotoma*, epiphytic on stems of the seagrass *Amphibolus*, is widespread in southern Australia. It is characterised by the typical dumontiaceous female reproductive system but is multiaxial, in contrast to most other genera of the Dumontiaceae; tetrasporangia are unknown. Because of the common occurrence of the very distinctive female reproductive system throughout the Dumontiaceae sensu lato and the demonstration that certain genera have a juvenile uniaxial thallus which becomes multiaxial when mature, recognition of the segregate families Weeksaceae and Dilseaceae is not supported.

THE DUMONTIACEAE (CRYPTONEMIALES: RHODOPHYTA) OF SOUTHERN AUSTRALIA

by E. ANN SHEPLEY* & H. B. S. WOMERSLEY†

Summary

SHEPLEY, E. ANN & WOMERSLEY, H. B. S. (1983) The Dumontiaceae (Cryptonemiales: Rhodophyta) of southern Australia. *Trans. R. Soc. S. Aust.* **107**(4), 201-217, 30 November, 1983.

Four genera and species of Dumontiaceae are known from southern Australian seas. *Dasyphloea insignis* Montagne occurs from Wanna, S. Aust., to Waratah Bay, Vic., and around Tasmania; *Dudresnaya australis* J. Agardh from King Georges Sound, W. Aust., to Western Port, Vic., and the north coast of Tasmania; and a single collection from the Isles of St Francis, S. Aust., is referred to *Acrosymphyton taylorii*, previously known from the Hawaiian Islands. The reproduction of these species is described in detail. A new genus and species, *Kraftia dichotoma*, epiphytic on stems of the seagrass *Amphibolis*, is widespread in southern Australia. It is characterised by the typical dumontiaceous female reproductive system but is multiaxial, in contrast to most other genera of the Dumontiaceae; tetrasporangia are unknown. Because of the common occurrence of the very distinctive female reproductive system throughout the Dumontiaceae *sensu lato* and the demonstration that certain genera have a juvenile uniaxial thallus which becomes multiaxial when mature, recognition of the segregate families Weeksaceae and Dilseaceae is not supported.

KEY WORDS: Southern Australia, Dumontiaceae, *Kraftia*.

Introduction

Members of the Dumontiaceae on southern Australian coasts are not well known and generally not common, apart from occasional abundance in particular localities. They include *Dasyphloea insignis* Montagne (the commonest) which has been studied previously by the first author (Mitchell 1966), and a species of *Dudresnaya* to which two names have been applied: these are the European *D. coccone* (C. Agardh) Crouan & Crouan [= *D. verticillata* (Withering) Le Jolis] by Harvey (1855, p. 558) and *D. australis* J. Agardh. In addition, a single specimen of *Acrosymphyton* is known from the Isles of St Francis, South Australia and is referred to *A. taylorii* Abbott, and a new and distinctive genus, *Kraftia*, is described below.

An account of these genera, with further notes on the distribution and synonymy of *Dasyphloea insignis*, is given here.

Family DUMONTIACEAE

Thallus usually erect, branched, often soft and mucoid, uniaxial with 4(-6) periaxial cells or multiaxial, with a loose or usually a

compact cortex and a medulla with filaments of slender or swollen cells and usually with additional descending rhizoids. Gametophyte and tetrasporophyte isomorphic, or heteromorphic with the tetrasporophyte prostrate and usually crustose.

Gametophytes usually dioecious, in some taxa monoecious. Female gametophyte with carpogonial branches and auxiliary cell branches on separate and often distant periaxial or medullary cells, both of numerous cells and unbranched or bearing short laterals. Carpogonial branches usually reflexed over the terminal 3-4 cells, with several larger cells below: fertilized carpogonium producing a connection to a lower nutritive cell in the carpogonial branch, which then develops connecting filaments to auxiliary cells but in some genera (with non-functional auxiliary cells) producing gonimoblast cells directly. Auxiliary cell branches straight or curved, with or without short laterals, with the auxiliary cell terminal or intercalary and usually smaller than adjacent cells. Carposporophytes remaining attached to the auxiliary cell branches, with radiating gonimoblast filaments and all cells becoming carposporangia apart from the basal fusion cell, situated within the inner cortex or outer medulla with the adjacent cortex swollen or not. Spermatangia cut off from outer cortical cells, scattered or in groups.

* c/o Western Australian Herbarium, Department of Agriculture, George Street, South Perth, W. Aust. 6151.

† Department of Botany, University of Adelaide, Adelaide, S. Aust. 5000.

Tetrasporophytes similar to gametophytes or prostrate and usually crustose. Tetrasporangia zonate or cruciate, often irregularly divided in crustose sporophytes, produced from cortical cells.

Type genus: Dumontia Lamouroux.

A family of some 15 genera (Kylin 1956, p. 148; Mitchell 1966, p. 216), three of which have been placed in the segregate family Weeksaceae (Abbott 1968). The largest number of genera (8) occur on Pacific North American coasts, and the family is apparently only known in the southern hemisphere from Australia, apart from *Leptocladia peruviana* Howe (1914, p. 176) from northern Peru.

Key to southern Australian genera of Dumontiaceae

- 1 Thallus irregularly laterally branched, uniaxial, with prominent axial cells bearing whorls of periaxial cells and ultimately a compact to loose cortex 2
- 1 Thallus subdichotomous, multiaxial, with thin but compact cortex bearing thick-walled, tapering hairs *Kraftia*
- 2 Carpogonial branches bearing short lateral branches, with fusion between the fertilised carpogonium and cells of these laterals; auxiliary cell terminal on auxiliary cell branch; heteromorphic with a prostrate, filamentous tetrasporophyte (unknown in *A. taylorii*) *Acrosymphyton*
- 2 Carpogonial branches generally without laterals, fertilised carpogonium fusing with cell(s) 3-5 of the branch; auxiliary cell intercalary in auxiliary cell branch; isomorphic gametophytes and tetrasporophytes 3
- 3 Cortex compact; persistent, acicular, unicellular hairs present on outer cortical cells; carpogonophytes in small numbers, each causing localised swelling of the thallus *Dasyphloea*
- 3 Cortex loose; acicular unicellular hairs not present on outer cortical cells; carpogonophytes numerous, scattered, not causing swelling of thallus *Dudresnaya*

Genus ACROSYMPHYTON Sjøstedt 1926:8

Heteromorphic, with erect, branched gametophytes and prostrate, filamentous tetrasporophyte (known only in type species).

Gametophytes dioecious or monoecious, erect, mucoid, irregularly much branched with axes bearing laterals of several orders. Uniaxial with whorls of four periaxial cells pro-

ducing lateral filaments of cells with the outer forming a loose cortex surrounding the medulla; some distance below the branch apices, periaxial and inner medullary cells produce descending rhizoids. Female gametophytes with carpogonial and auxiliary cell branches scattered throughout the thallus, borne on periaxial or inner medullary cells. Carpogonial branches several cells long, with several of the mid cells bearing short lateral branches each 1-4 cells long, with post-fertilisation fusions to these cells prior to formation of connecting filaments. Auxiliary cell branches 5-9 cells long with a terminal auxiliary cell. Carposporophytes compact, with all cells developing into carposporangia. Spermatangia clustered on outer cortical cells.

Tetrasporophyte prostrate, of branched filaments, "Hymenoclonium-like", producing tetrahedral tetrasporangia, or "seriate tetrasporangia" which reproduce the tetrasporophyte.

Type species: A. purpuriferum (J. Agardh) Sjøstedt.

A genus of four species, the type from the Mediterranean, *A. caribaeum* (J. Agardh) Sjøstedt from Bermuda and Florida, *A. taylorii* Abbott from the Hawaiian Islands and Australia, and *A. firmum* Hawkes (1982) from New Zealand. The tetrasporophyte was unknown until Cortel-Breeman & van den Hoek (1970) cultured *A. purpuriferum* and showed that this species is heteromorphic with a prostrate tetrasporophyte.

Acrosymphyton taylorii Abbott 1962:845.

figs 1-9. Womersley 1981:303,

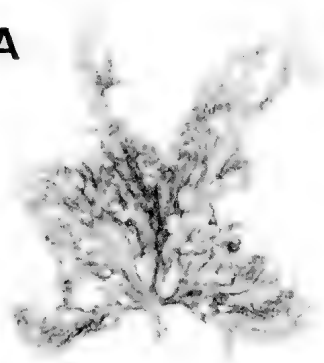
FIGS 1A,B,3

Thallus (Australian plant) medium red, about 4 cm high (Fig. 1A), with a short main axis about 2 mm broad producing laterals of similar diameter bearing slender, tapering branches for 3 or 4 orders. Uniaxial (Fig. 1B) with each axial cell bearing 4 periaxial cells which produce lateral filaments with several orders of cells, the outer forming a loose cortex (Fig. 3A) and with many of the inner medullary cells producing descending rhizoids.

Gametophytes dioecious. Carpogonial branches, (Fig. 3B,C) developing from periaxial cells or from second or third order cells

Fig. 1. A. *Acrosymphyton taylorii* (ADU, A38045). B. *A. taylorii*. Apex of uniaxial branch with periaxial whorls; young auxiliary cell branch on lower right (ADU, A38045). C. *Dasyphloea insignis*. Type sheet in PC. D. *D. insignis*. Specimens from Robe, cystocarpic on right, male upper left tetrasporangial lower left (ADU, A43343).

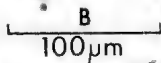
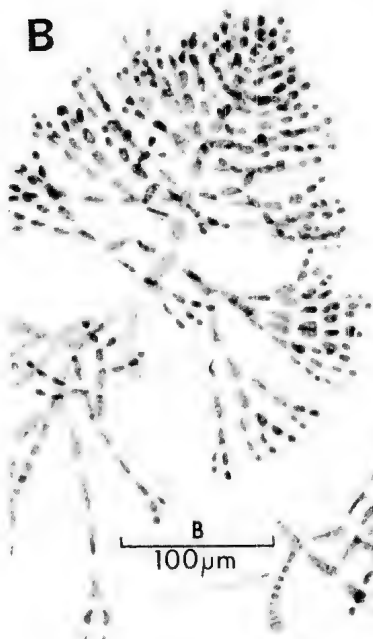
A



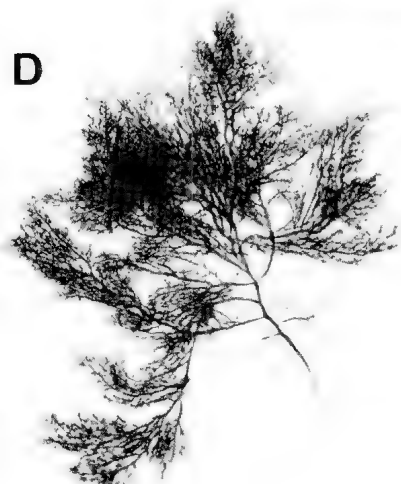
C



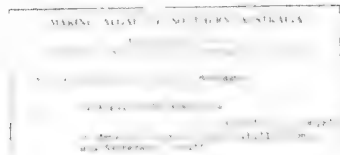
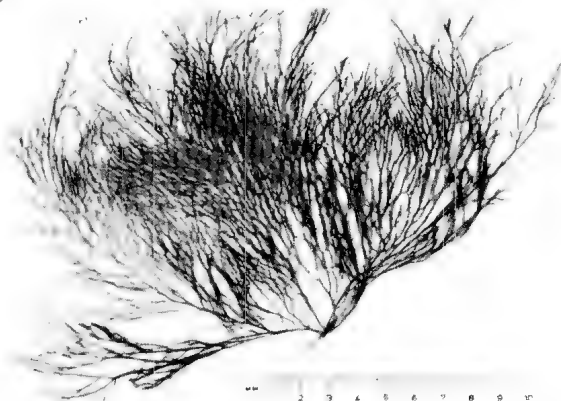
B



D



Dalmanella integrum Montg.
Dalmanella integrum Montg.
Dalmanella integrum Montg.



of the lateral filaments, replacing one of the vegetative filaments on their bearing cell, 9–10 cells long with the carpogonium sharply reflexed towards cells 4 and 5 (Fig. 3C,D) and a long and usually basally coiled trichogyne. One to four cells nearest the base of the carpogonial branch produce no laterals but the next 5–6 cells form distichous lateral branches 2–4 cells long (Fig. 3C), which may further cut off 1–2 celled side branches towards the recurved carpogonium; the cell below the carpogonium does not cut off lateral cells. Post-fertilisation fusion occurs between the carpogonium and terminal cells of these lateral branches (Fig. 3D,E), usually those from cells 4 and 5 of the carpogonial branch, while the cell below the carpogonium remains densely cytoplasmic. This fusion produces several connecting filaments with basal pit-connections (Fig. 3E). Auxiliary cell branches (Fig. 3A) develop in similar positions to the carpogonial branches, and are 5–9 cells long without lateral cells and with a larger, subspherical, terminal auxiliary cell, with which a connecting filament fuses (Fig. 3F) and initiates gonimoblast cells (Fig. 3G); each connecting filament usually continues to further auxiliary cells (Fig. 3F). Carposporophytes (Fig. 3G,H) globular, scattered in the outer medulla, 80–100 μm in diameter, with nearly all cells becoming subspherical carposporangia 12–20 μm in diameter. Male gametophytes (Hawaiian plants) smaller than female gametophytes, with small clusters of spermatangia on outer cortical cells.

Tetrasporophytes unknown.

Type locality: Hauula, Oahu, Hawaiian Islands.

Holotype: Abbott 1461 (2), in BISH. Isotypes in UC (912181) and BISH.

Distribution: Only previously recorded from Oahu.

Australian record: Egg 1, Isles of St Francis, S. Aust., 32–38 m deep (Shepherd, 11.5.1971; ADU, A38045).

This is the first published record of *A. taylorii* from outside the Hawaiian Islands, but it has also been collected from deep water off One Tree Island on the Great Barrier Reef, Old and Lord Howe Island (pers. comm. G. T. Kraft) and from Kyushu I., Japan (in Herb. T. Tanaka, pers. comm. I. A. Abbott).

This single specimen from southern Australia agrees well with *A. taylorii*, with only minor differences, but it is clearly desirable that more plants should be discovered and

further comparisons made. The specimen lacks the base and may be only part of a larger plant; it was also disintegrating when mounted.

Some apparent anomalies from the typical development of the female reproductive system have been observed. In one case a terminal cell of a lateral on a carpogonial branch appeared to have assumed the role of an auxiliary cell, showing fusion with a connecting filament and subsequent initiation of gonimoblast tissue (Fig. 3I). Taylor (1952, p. 34) for *A. caribaeum* mentioned occasional instances where terminal cells of the carpogonial branch laterals suggested by their isolation and size that they might be potential auxiliary cells.

Minor differences between the Hawaiian and Australian plants are that Abbott described both carpogonial and auxiliary cell branches as borne on the third or fourth order cells of the lateral filaments, whereas they frequently occur on the first (periaxial) and second order cells as well as third order cells in the Australian specimen. No membrane around the immature carposporophyte was observed in the latter plant, but this is probably no more than a gelatinous sheath which readily breaks down.

The differences between *A. taylorii* and the other two smaller species have been summarised by Abbott (1962, p. 847). *A. purpuriformis* is monoecious and has a shorter (3–6 celled) auxiliary cell branch, while *A. caribaeum* has a frequently subdivided auxiliary cell branch thus with several terminal auxiliary cells. Other differences in size of vegetative cells are discussed by Abbott. *A. firmum* differs in having regularly distichous branching.

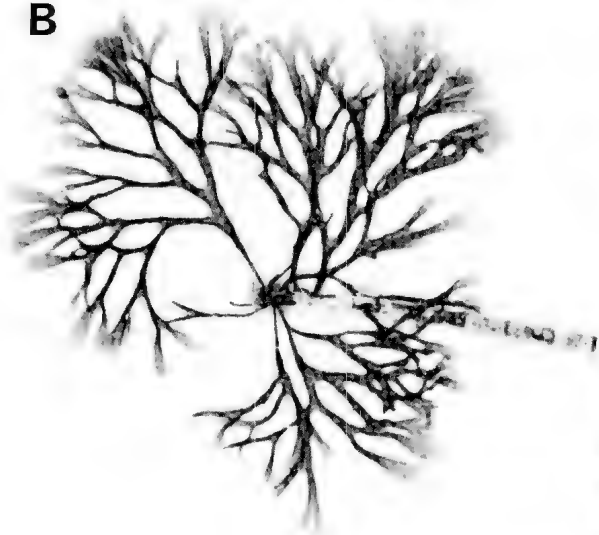
Abbott (1962, p. 847) discussed the earlier generic synonym of *Acroxymplyon*, viz. *Helminthopsis* J. Agardh (1899, p. 97), the type of which (*H. verticillifera* J. Agardh 1899, p. 98) has been shown to be identical with *A. caribaeum* (J. Agardh 1899, p. 84) Sjöstedt. Papenfuss (1958, p. 105) restored the older generic name *Helminthopsis*; but according to Abbott he later considered this a homonym of *Helminthopsis* Heer, a fossil alga described in 1877 and now considered to represent "feeding tracts of animals" (Index Nominum Genericorum 1979, p. 795). It may be debated whether these two names should be considered homonyms under Article 75 of the ICBN.

A

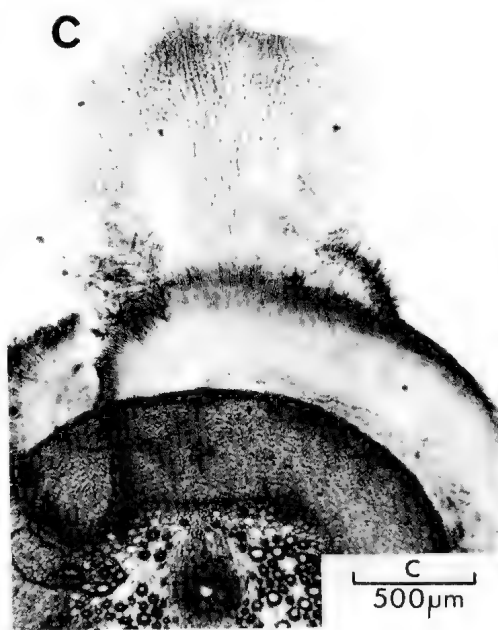


Dudresnaya australis J Ag
 Sta 2 inside Frying Shoal, St Vincent's Gulf
 10 m deep. S. Nov
 2.12.1964
 Col. S. S. Shepherd

B



C



C
 500µm

Fig. 2. A. *Dudresnaya australis* (ADU, A33469). B. *Kraftia dichotoma*. Holotype specimen (ADU, A52844). C. *K. dichotoma*. An erect multiaxial axis arising from the crustose base of a stem of *Amphibolis antarctica* (ADU, A43937).

Genus *DASYPHLOEA* Montagne 1842:8;
1845:102, pl. 8 fig. 3

FIG. 1C,D

Isomorphic. Thallus erect, with one or more axes radially and irregularly branched to several orders, branches tapering from base to apices. Uniaxial, with whorls of 4 periaxial cells each producing several orders of 3–4 elongate cells, then 2–3 layers of ovoid cells and 4–5 layers of small cells forming a compact cortex with the outermost forming a tomentum of acicular, thick walled, hyaline hairs as well as normal floridean hairs; periaxial and elongate medullary cells producing descending rhizoids, with the mature thallus differentiated into a filamentous medulla and pseudoparenchymatous cortex.

Gametophytes dioecious, male gametophyte with fewer acicular hairs. Carpogonial and auxiliary cell branches scattered throughout the thallus, borne on the lower side of periaxial and inner medullary cells. Carpogonial branches 5–6 cells long, reflexed with the carpogonium lying adjacent to cell 4. and cells 4, 5 and 6 larger than cells 2 and 3. Following fertilisation, the carpogonium fuses with cell 4 (sometimes with cells 5 and 6) and the fusion cell produces several connecting filaments each with a basal pit-connection. Auxiliary cell branches 12–15 cells long, curved, with the auxiliary cell usually 4(3–5) from the apex and slightly smaller and less densely staining than other cells. Carposporophytes prominent, swelling and distorting the thallus, with radiating gonimoblast filaments each cell of which becomes a carposporangium, and developing a comparatively large basal fusion cell. Spermatangia cut off from the outermost cortical cells in groups of 2–3, elongate.

Tetrasporophytes more robust and less branched than gametophytes, producing large, zonate tetrasporangia from inner cortical cells. *Type and only species:* *D. insignis* Montagne 1842:8; 1845:102, pl. 8 fig. 3. Mitchell 1966: 210, pls 22–26.

Additional synonym. *Chylocladia multiramea* Sonder 1853:681, type from Lefevre Pen., S. Aust. (*F. Mueller*, 16.xii.1847; MEL 45196).

Type locality: Probably Tasmania (see below).

Distribution: From Wanna, Eyre Pen., S. Aust., to Waratah Bay, Vic., and around Tasmania. Sublittoral, known from depths of 2–17 m.

Selected specimens: Wanna, S. Aust., drift (*Womersley*, 19.ii.1959; ADU, A22373). Aldinga, S. Aust., drift on *Amphibolis* (*Womersley*, 23.iv.1973; ADU, 43343—"Marine Algae of southern Australia" No. 154). Stanley Beach, S. coast Kangaroo I., S. Aust., drift (*Womersley*, 27.i.1956; ADU, A20380). Waratah Bay, Vic., drift (*Sinkora* A2165, 7.iii.1975; ADU, A48554). Dover, Tas., drift (*Wollaston & Mitchell*, 27.ii.1964; ADU, A27699).

D. insignis was described in detail by Mitchell (1966), who commented that the type locality is probably Tasmania rather than Akaroa, New Zealand (see also *Womersley* 1983).

Dasyphloea is characterised by the uniaxial thallus, compact cortex bearing prominent acicular hairs, carpogonial and auxiliary cell branches without lateral cells, and by the zonate tetrasporangia on isomorphic tetrasporophytes.

Genus *DUDRESNAYA* Crouan & Crouan
1835:98, pl. 2 figs 2,3 (nom. cons.)

Isomorphic. Thallus erect, mucoid, usually much branched with terete or flattened branches, sometimes with a slight annular appearance. Uniaxial, with whorls of 4(–6) periaxial cells when mature, each producing 2–4 elongate cells for several orders, with the outermost forming a loose to moderately compact cortex bearing floridean but not acicular hairs; descending rhizoids usually developed from medullary cells.

Gametophytes usually dioecious. Carpogonial and auxiliary cell branches scattered throughout the thallus, borne on periaxial or inner medullary cells. Carpogonial branches several cells long, straight or terminally reflexed, usually with the carpogonium fusing with cells 4 or 5 of the carpogonial branch, followed by production of several connecting filaments from the fusion cell, each with a basal pit-connection. Auxiliary cell branches of numerous cells (10–20), with the smaller auxiliary cell in the middle or lower half of the branch. Carposporophytes compact, globular, situated within the outer medulla often with ones of different ages intermixed, scarcely swelling the thallus, with all cells becoming carposporangia. Spermatangia cut off in clusters from outer cortical cells.

Tetrasporophytes similar to gametophytes, with large, zonate tetrasporangia cut off terminally from cells of the outer medulla or inner cortex.

Type species: D. coccinea (C. Agardh) Crouan & Crouan (type cons.) [= *D. verticillata* (Withering) Le Jolis].

A genus of some nine species (Eiseman & Norris 1981, p. 187), with the type species from Europe and the other species from the tropical American Atlantic or the Pacific. The single species (*D. australis* J. Agardh 1899) from southern Australia is one of the earliest described species of the genus, though J. Agardh expressed doubt on its distinctness in his original brief description; it was described more fully by Setchell (1912).

Dudresnaya australis J. Agardh 1899: 85.

De Toni 1924: 559. Mitchell 1966: 215. Setchell 1912: 245, pl. 27, fig. 9. Wilson 1892: 181 (nomen nudum).

D. coccinea sensu Harvey 1855: 558. Sonder 1881: 15.

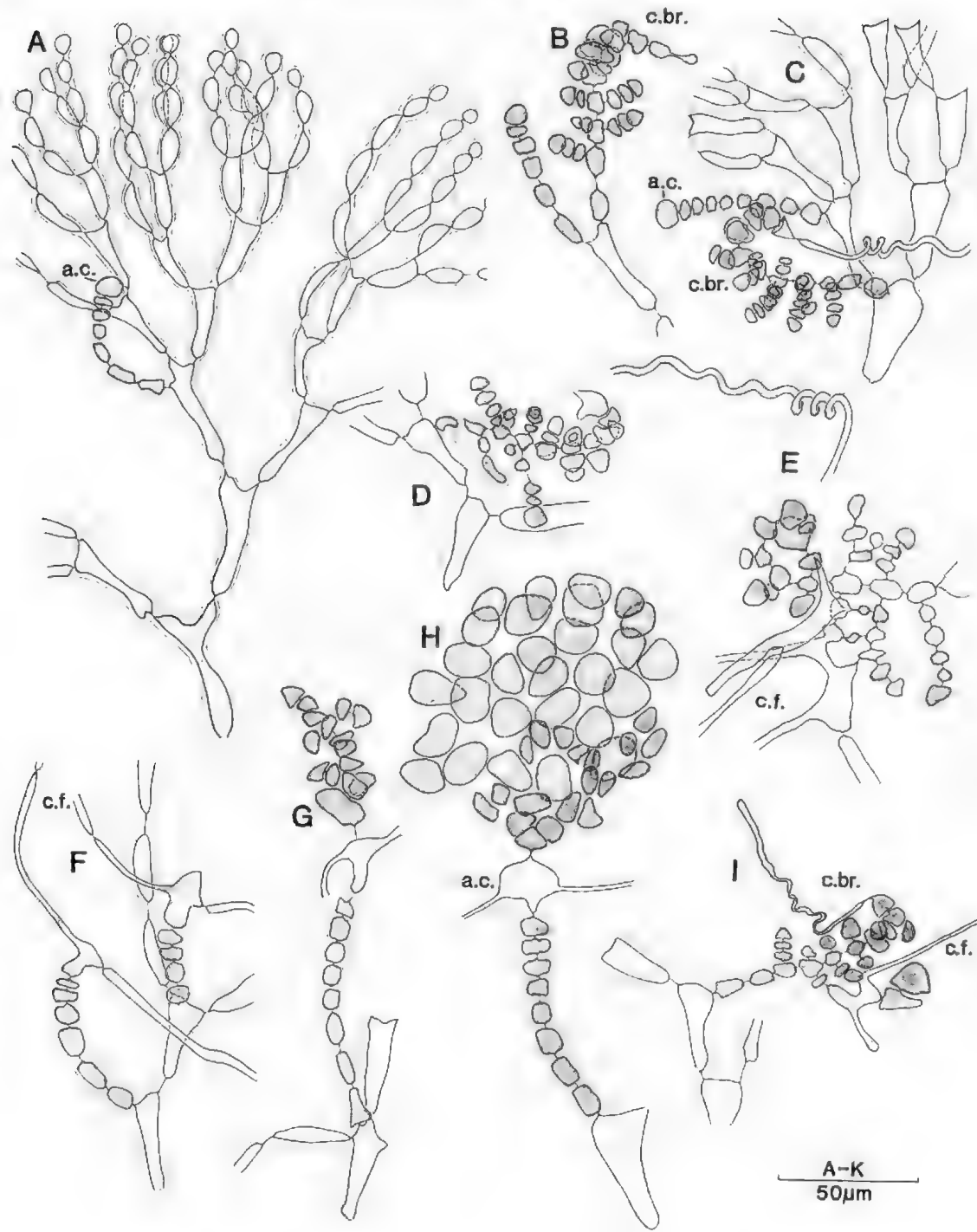
FIGS 2A,4

Thallus (Fig. 2A) rose red to dark red-brown, erect and much branched, spreading, variable in robustness, 5–16 cm high, mucoid, with a main axis 2–3 mm in diameter bearing irregularly radially arranged laterals to 3 or 4 orders, terete and tapering and 0.5–1 mm in diameter in lesser branchlets which are alternate to opposite. Uniaxial, with an apical cell dividing transversely and producing cylindrical axial cells becoming 300–400 μm long and 50–200 μm broad, and when mature bearing 4(–6) periaxial cells bearing tufted branches which are basally divided at each or most cells below, then unbranched and when mature gently tapering, usually 12–16 cells long with cells (5–)8–14 μm broad and L/B 2–3(–5). The outer medulla grades to the cortex and the outer cortical cells near branch apices bear long, slender, floridean hairs. Young thallus branches usually show slight annulations corresponding to the periaxial whorls. Each periaxial cell also produces a descending rhizoid of elongate cells, each cell of which may produce a lateral branch system similar to and lying between the periaxial whorls, and resulting in a more continuous medulla and cortex. The descending rhizoids pass down over two or three axial cells and thus each axial cell becomes surrounded by 12–18 rhizoids, which ultimately enlarge to similar diameter to the axial cells and tend to obscure the latter. In the mature thallus, numerous secondary descending rhizoids develop from other cells of the periaxial laterals, forming an interwoven filamentous medulla. Lateral branches develop usually from periaxial cells.

Gametophytes dioecious. Carpogonial branches (Fig. 4A,B) develop usually on periaxial cells of lateral thallus branches, and are 6–10 cells long with the upper 3 cells reflexed and cells 2 and 3 smaller; the basal or sub-basal cell frequently bears a single lateral cell (Fig. 4C). Following fertilisation, an extension from the carpogonium fuses with cell 4 (Fig. 4C) and frequently extends to cell 5, and the resultant large fusion cell produces several connecting filaments each with a basal pit-connection. Each connecting filament grows towards the branch apex and fuses with one and usually more auxiliary cells as the latter develop. Auxiliary cell branches (Fig. 4D,E) develop from periaxial cells and also from basal cells of lateral branch systems developed from the descending rhizoids, and thus considerably outnumber the carpogonial branches. However, nearly all auxiliary cells are contacted by connecting filaments (Fig. 4E,F) and many carposporophytes result. Each auxiliary cell branch is 11–20 cells long, with 3–5 mid cells larger and the central of these (often fifth from the base) the smaller, compressed auxiliary cell (Fig. 4D); the terminal 6–8 cells often taper and a sterile lateral cell may occur on the basal cell (Fig. 4F) as in carpogonial branches. Two gonimoblast initials develop opposite the fusion side of the auxiliary cell (Fig. 4G). Carposporophytes (Fig. 4H) compact (initially two lobed), 100–175 μm in diameter with most cells forming rounded carposporangia about 12 μm in diameter. Carposporophytes of different ages occur scattered profusely in the outer medulla, but scarcely swelling the thallus. Male gametophytes with spermatangia formed in dense clusters (Fig. 4I,J) from 1–4 terminal and subterminal cells of the outer cortex. Setchell (1912, p. 246) reported Wilson's collections to be monoecious, but all sexual specimens in our material were dioecious.

Tetrasporophytes have denser rhizoidal development than gametophytes, and this obscures the basic whorled branch pattern to a greater extent. Large, zonate tetrasporangia (Fig. 4K), 30–45(–50) μm long and 15–20 μm in diameter, develop terminally or laterally on outer medullary cells of both the periaxial branch systems and those arising from the descending rhizoids. Further tetrasporangia may arise from short branches originating below the earlier tetrasporangia.

Type locality: Port Phillip, Victoria (William 28.23.1888).



Holotype: Herh. Agardh, LD, 34730.

Distribution: Known from King George's Sound, W. Aust. (Harvey, Trav. Ser. 325), Pearson I., S. Aust., 15 m deep (Shepherd, 8.i.1969; ADU, A33940), Point Avid, S. Aust., drift (Christophel, 7.xii.1976; ADU, A478213), Tipara reef, Spencer Gulf, S. Aust., 5 m deep (Shepherd, 24.ix.1971; ADU, A39743), 6 m deep (Shepherd, 29.i.1972; ADU, A41865) and 11 m deep (Shepherd, 23.xii.1970; ADU, A38264, A38257, and 13.xii.1971; ADU, A41222), Investigator Strait, S. Aust., 33 m deep (Watson, 20.i.1971; ADU, A38583), Arno Bay, S. Aust., drift (Kraft, 12.xi.1971; ADU, A42247), N. Spencer Gulf, S. Aust., 8 m deep (Shepherd, 4.ix.1973; ADU, A44148), Off Troubridge I., S. Aust., 14 m deep (Shepherd, 2.ii.1969 and 4.ii.1969; ADU, A33468 and ADU, A33790) and 24 m deep (Shepherd, 5.ii.1969; ADU, A33861, male), Inside Tapley Shoal, S. Aust., 10 m deep (Shepherd, 2.ii.1969; ADU, A33469), Outside Tapley Shoal, S. Aust., 15 m deep (Shepherd, 2.ii.1969; ADU, A33508), American R. inlet, Kangaroo I., S. Aust., drift at jetty (Womersley, 31.x.1966; ADU, A30830), Western Port, Vic. (Wilson, 5.ii.1894; MEL 5333), Flinders, Vic., drift (Womersley & Mitchell, 18.i.1967; ADU, A31501), Low Head, Tas. (Perrin 325 and Lucas, Jan. 1930; BM).

D. australis is a sublittoral species known from 5 to 33 m deep and is commonly epiphytic on the seagrass *Amphibolis*, but also on the brown alga *Codium*.

Since the comments of Mitchell (1966, p. 216) on tetrasporangial plants, female and male gametophytes have been found in several collections.

D. australis is closely related to the type species, *D. coccinea* but differs in having longer medullary-cortical filaments with longer unbranched terminal parts. Setchell (1912, p. 246) suggested that *D. australis* had longer auxiliary cell branches (11–20 cells) compared to about 12 in *D. verticillata*, but Littler (1974, fig. 10) illustrates a branch 15 cells long; sterile dichotomous terminal parts on the auxiliary cell branches (Setchell 1912, p. 246) of *D. australis* have not been observed in this study.

Genus **KRAFTIA** gen. nov.

Kraftia dichotoma sp. nov.

FIGS 2B,C,5

Thallus (Fig. 2B) erect, 1–3 cm high, subdichotomous, developed from a prostrate pad extending around the lower stems of *Amphibolis*; branches slightly compressed, 2–3 mm across near the base and tapering to about 1 mm in diameter near the rounded apices. Multiaxial (Fig. 2C), with a filamentous medulla and a narrow, compact cortex, with the outer cortical cells bearing hyaline, thick walled and terminally rounded hairs (Fig. 5A) bent towards the branch apex.

Gametophytes monoecious, with carpogonial and auxiliary cell branches scattered in the outer medulla. Carpogonial branches (Fig. 5B) 9–12 cells long with the carpogonium sharply reflexed, cells 2 and 3 small and cells 4 and 5 larger and densely cytoplasmic, with post-fertilization fusion (Fig. 5D) between the carpogonium and cell 4, resulting in an enlarged fusion cell producing several connecting filaments with basal pit-connections; lower cells of the carpogonial branch may bear single sterile cells laterally (Fig. 5B). Auxiliary cell branches (Fig. 5C,E,F) 9–14 cells long, with the auxiliary cell usually fourth or fifth from the apex and slightly laterally displaced, with all the cells below and often above the auxiliary cell forming short lateral branches. Carposporophytes (Fig. 5G) initially with 3–4 groups of gonimoblast cells, becoming globular with most cells forming carposporangia, scattered in the outer medulla and not distending the cortex. Spermatangia (Fig. 5H) cut off from the outer cortical cells.

Tetrasporangia unknown.

Thallus subdichotomus, ex pulvino basali prostrato circum caulem *Amphibolis* oriens. Multiaxialis medulla filamentosa et cortice angusta compacta, cellulae corticales exteriores pilos hyalinos crassiparietosos decrecentes ad apices ramorum portatae.

Fig. 3. *Aeriosymphyton taylorii* (ADU, A38045). A. Periaxial branch system with a young auxiliary cell branch. B. Carpogonial branch with young carpogonium (on right) and auxiliary cell branch (on left). C. Mature carpogonial branch and adjacent auxiliary cell branch. D. Carpogonial branch just post-fertilisation, with extension from carpogonium. E. Carpogonial branch (post-fertilisation) with connecting filaments from cells of the laterals to the carpogonial branch. F. Two auxiliary cell branches with connecting filaments fused with the auxiliary cells and continuing growth. G. Young gonimoblast developing from auxiliary cell. H. A young carposporophyte surmounting an auxiliary cell branch. I. A carpogonial branch with a terminal lateral cell acting as an auxiliary cell and fused with a connecting filament from which gonimoblast cells are arising. a.c.—auxiliary cell; c.br.—carpogonial branch; c.f.—connecting filament.

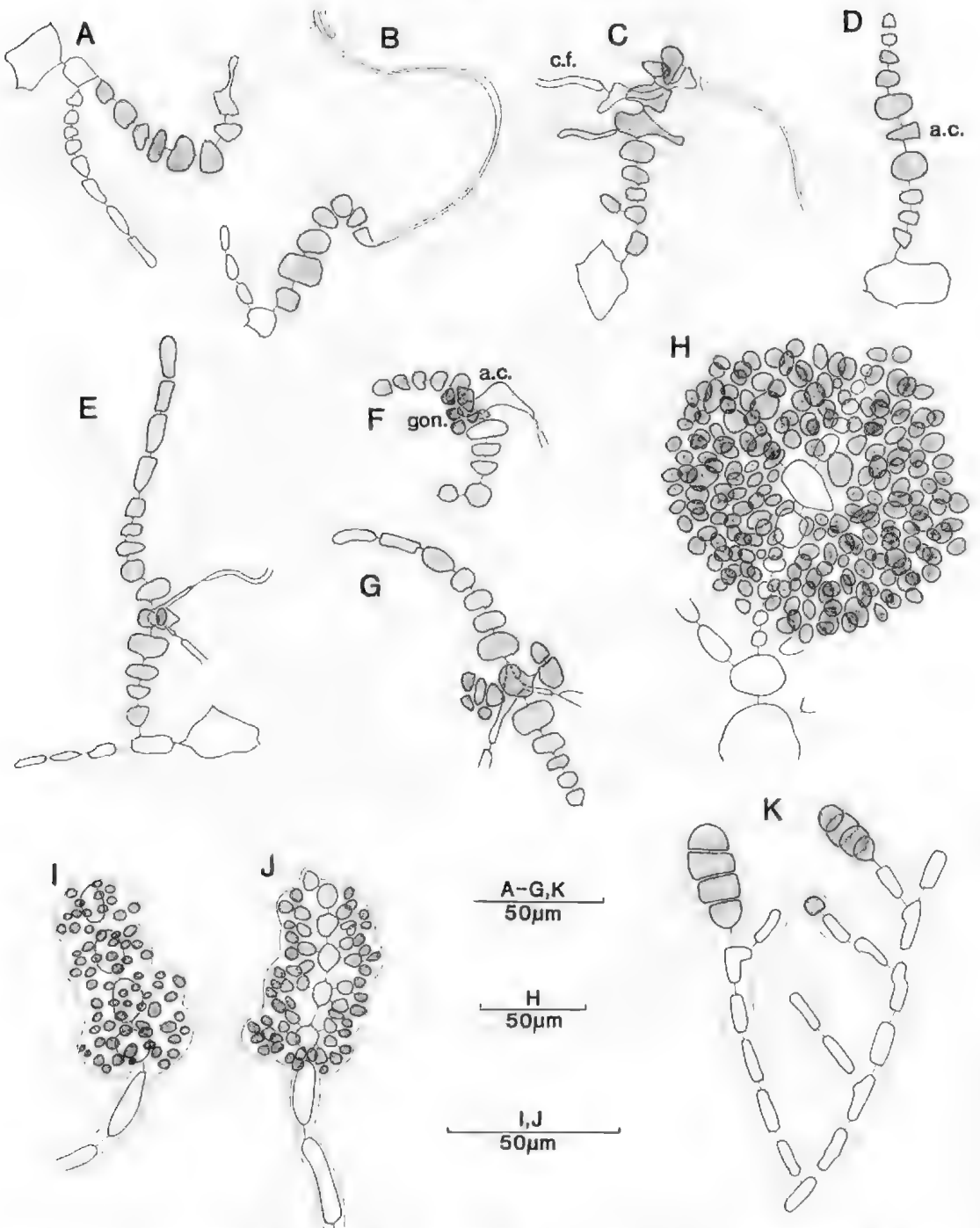


Fig. 4. *Dudresnaya australis*. A-H, K, ADU, A30830. A. Young carpogonial branch. B. Mature carpogonial branch. C. Post-fertilisation carpogonial branch with developing connecting filaments. D. Auxiliary cell branch. E. Auxiliary cell branch with connecting filament fused to auxiliary cell, continuing growth, and with one gonimoblast cell. F. Early gonimoblast development from an auxiliary cell. G. Later gonimoblast development. H. Mature carposporophyte; auxiliary cell branch not stippled. I, J, ADU, A33861. I. Spermatangial branch, surface view. J. Spermatangial branch, sectional view. K. Tetrasporangia. a.c.—auxiliary cell; c.f.—connecting filament; gon.—gonimoblast.

Gametophyta dioecia. Ramuli carpogoniales 9–12 cellularum longitudine, carpogonium reflexum, carpogonium cellula quarta coalescens, celluliconjuncta filamentos plures conjungentes efferens; cellulae inferiores rami carpogonialis ramos breves laterales ferre possint. Rami auxiliari-cellulae 9–14 cellulae longitudine, auxiliari cellula 4–5 cellulae ab apice, lateraliter plus minusve depulsa, cellulae aliae ramos breves laterales facientes. Carposporophyta globosa, in medulla exteriori dispersa, corticem non distendenda, cellulae pro parte maxima carposporangia facientes. Spermatangia cellulis exterioribus corticalibus abscissa.

Tetrasporangia incognita.

Type locality: Victor Harbor, S. Aust., 6 m deep (Clarke, 30.xii.1981).

Holotype: ADU, A52844. Isotypes distributed to MEL, NSW, PERTH, UC, BM, PC, L, LD and other herbaria.

Distribution: From Port Denison, W. Aust. to Westernport Bay, Vic., always on lower stems of *Amphibolis* (*A. antarctica* and *A. griffithii*). *Known specimens:* Port Denison, W. Aust., drift (Kraft 4136, 14.xii.1971; ADU, A50319). Elliston, S. Aust., 7 m deep (Shepherd, 25.x.1971; ADU, A42950). Tiparra reef, S. Aust., 5–6 m deep (Shepherd, 2.iv.1971, 24.ix.1971, 5.xi.1971, 29.i.1972 and 10.xii.1973; ADU, A39121, A39744, A38347, A41868 and A44596 resp.) and 11 m deep (Shepherd, 23.xii.1970, 5.xi.1971, and 13.xii.1971; ADU, A38252, A38339 and A41216 resp.). Venus Bay, S. Aust., drift (Womersley, 12.ii.1954; ADU, A19501). Port Victoria, S. Aust., 3–4 m deep (Kraft, 20.ix.1973; ADU, A44547). Stenhouse Bay, S. Aust., 3–7 m deep (Kraft, 18.ix.1973; ADU, A44561). Victor Harbor, S. Aust., 5–7 m deep (Clarke, 23.xii.1981; ADU, A52822). Robe, S. Aust., 1–2 m deep near jetty (Mitchell, 10.ii.1973; ADU, A42983 and 16.ii.1974; ADU, A44664). D'Estree Bay, Kangaroo I., S. Aust., drift (Kraft, 16.i.1974; ADU, A45064). Queenscliff, Vic., drift (Norris, 21.i.1963; ADU, A27481). Cats Bay, Phillip I., Vic. (Norris, 20.i.1963; ADU, A27482). Walkerville, Vic., drift (Sinkora A2259, 2.iii.1976; ADU, A48514).

Kraftia dichotoma probably occurs on *Amphibolis* anywhere within the distribution of this seagrass, in areas of moderate water movement. It is usually confined to the lower stems in lower light intensity within the leafy canopy.

Kraftia is named in honour of Dr G. T. Kraft, who has contributed significantly to our knowledge of red algae of the orders Cryptonemiales and Gigartinales. It had previously been referred to provisionally as *Polynema* (a

pre-occupied name) and is so recorded by Ducker, Foord & Knox (1977, p. 86).

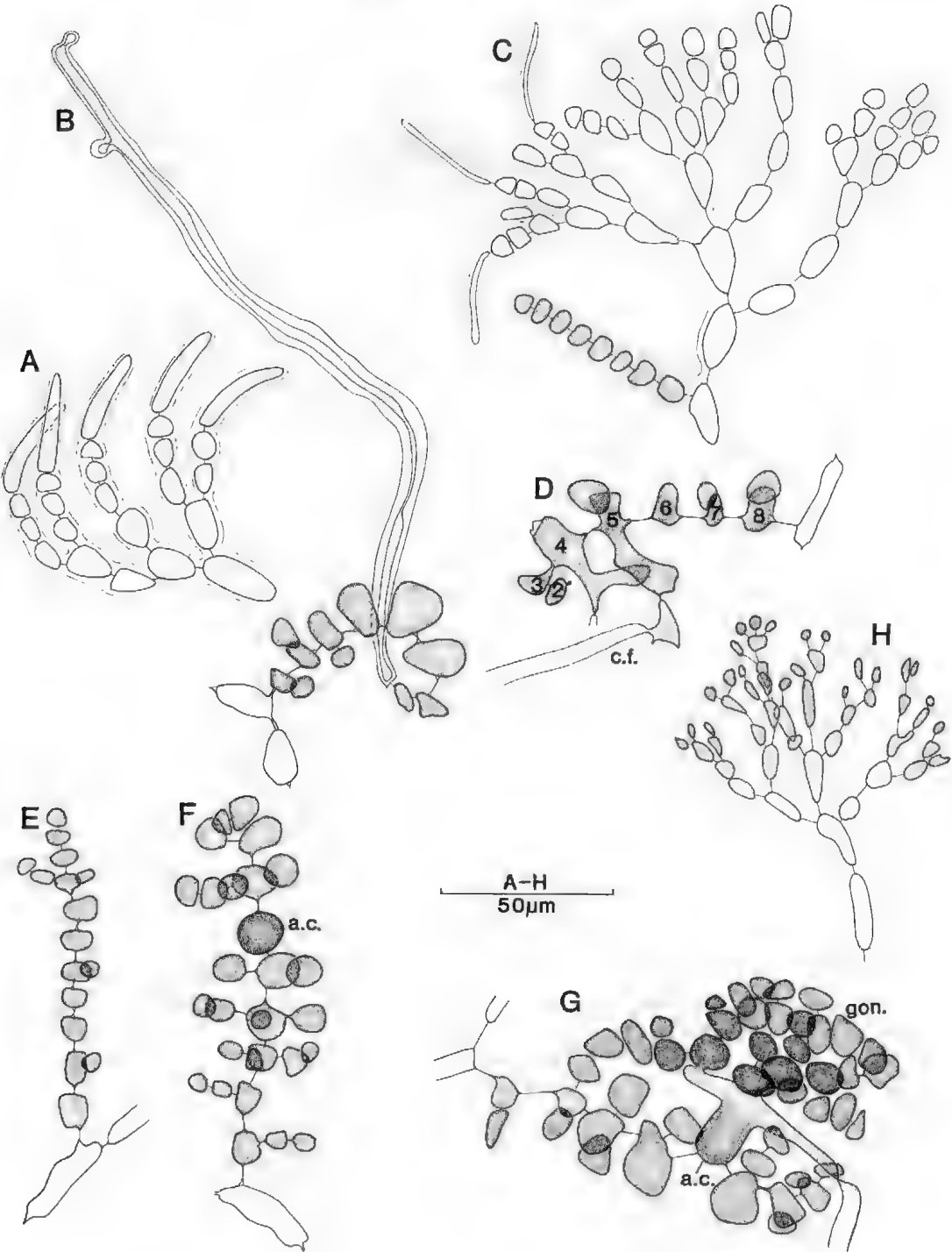
Thallus structure: The purplish-red thallus varies from a slightly branched plant one cm or so high to, when well developed, a rounded, much branched tuft to 3 cm high and 4–5 cm across, attached to the *Amphibolis* stem by a smooth, prostrate pad partly or almost entirely surrounding the host stem and up to 1 cm across in large plants. *Kraftia* apparently overwinters as the prostrate thallus, since winter collections (e.g. June to August) show only a basal pad or very early development of erect axes.

The prostrate pad consists of basal, spreading, branched filaments, from each cell of which arises an erect filament. These closely packed, vertical chains (Fig. 2C) of up to 20 cells remain largely unbranched, with the upper cells smaller and more rounded. The firm, smooth-surfaced pad attains a thickness of 0.5 mm near its centre.

The development of an erect axis (Fig. 2C) from this prostrate pad involves the simultaneous elongation and continued growth of a group of the vertical filaments over an area usually 0.5–1.0 mm in diameter. Thus the multiaxial erect thallus results directly from continued development of a group of erect pad filaments. Several erect axes may arise from one such pad, with new axes arising throughout the summer growth period.

An erect axis usually branches close to its base and continues for 7 or 8 subdichotomies. Axes near their base are 2–3 mm broad and slightly compressed; above they are almost terete and taper to about 1 mm in diameter. The thallus is soft in consistency, especially near the apices before the outer cells are consolidated into a firmer cortex. Colour when fresh is purplish-red, with a silvery bloom due to the cover of thick-walled hyaline hairs on the surface of the cortex; longer floridean hairs are also plentiful (Fig. 5C).

The multiaxial thallus shows apical growth of the numerous apical filaments, which branch at most cells and differentiate into a broad, filamentous medulla of elongate cells laterally connected by frequent secondary pit-connections, and a compact cortex of dichotomous filaments of small cells 5–8 μ m in diameter. The small apical cells of the central, longitudinal medullary filaments are curved in towards the centre and protected by the rapidly developing cortex from slightly older and more



lateral medullary cells. In longitudinal view, one or occasionally two branch systems of cortical cells arise midway along each cell of the outer medullary filaments. The outermost cortical cells (particularly near an actively growing apex) each bear a hyaline, thick walled hair (Fig. 5A) similar to (but with rounded ends) those of *Dasyphloea*. These hairs in *Kraftia* differ in being sharply bent towards the apex of the branch and are thus closely appressed to the thallus surface.

Reproduction: All plants collected have been sexual and monoecious (apart from some young, sterile plants), and no tetrasporangia have been observed. Spermatangia are present especially during the early reproductive period (Sept. to Dec.), while collections in April have many mature carposporophytes and probably represent the end of the reproductive season.

Carpogonial branches arise laterally on cells of the outer medullary filaments and are 9–12 cells long when mature. The carpogonium is sharply reflexed along the carpogonial branch (Fig. 5B), with two small cells (2 and 3) accommodating this flexure. Cells 4 and 5 are larger and densely cytoplasmic, and below them are 4–7 smaller, lightly staining cells, some of which bear short, 1–2 celled, laterals (Fig. 5B) which often are better developed following fertilisation. The long trichogyne is not markedly coiled and spermatia with connections to the trichogyne are often present near its summit (Fig. 5B).

Following fertilisation, fusion occurs between the carpogonium and cell 4 of the carpogonial branch (Fig. 5D), following which the enlarged fusion cell develops several protrusions which become connecting filaments, each with a basal pit-connection. Similar protrusions may develop from cell 5 without apparent connection of this cell with the carpogonium; however, in one case a small cell, apparently cut off from the carpogonium, was fusing with cell 5 and complete fusion of such a small cell may explain later development of connecting filaments from cell 5 without apparent connection to the carpogonium.

Auxiliary cell branches form in a similar position to the carpogonial branches and are usually more numerous; most, however, remain juvenile as a row of relatively small cells with few laterals (Fig. 5C). The mature auxiliary cell branch is 9–14 cells long (Fig. 5E,F) and the auxiliary cell is usually the fifth and is usually laterally displaced. The 3–4 (some times 2) cells distal to the auxiliary cell occasionally form branches, but all the lower (proximal) cells produce 1 or 2 celled laterals (Fig. 5F). A connecting filament fuses with the outer edge of the auxiliary cell (Fig. 5G) and gonimoblast development is initiated at 2–3 positions from nearby on the filament. The connecting filament usually continues growth to further auxiliary cells and pit-connections exist near the points of fusion and departure from the auxiliary cell.

Carposporophytes develop from 3–4 groups of gonimoblast cells, with most cells developing into globular to ovoid carposporangia 8–12 μm in diameter. The auxiliary cell remains as a "stalk" at the base of the branched gonimoblast filaments. The carposporophytes are numerous and scattered in mature thalli in autumn, but do not cause protrusion or distention of the cortical layer.

Spermatangia are cut off from the outer 3–4 layers of cortical cells (Fig. 5H).

Germination of carpospores: Carpospores of plants from Robe, S. Aust., collected in February 1973 (ADU. A42983) were germinated on slides in sterile seawater and in Provasoli ES and SWM3 (plus streptomycin) media at 16°C with a 14:10 hr regime and light intensity of 40–50 $\mu\text{E m}^{-2} \text{ s}^{-1}$. The medium was changed weekly. Later cultures were also established in 12°C and with short day conditions (8 hr L/16 hr D) under different light intensities, but without producing significantly different results in the cultures.

The rounder carpospores (Fig. 6A), about 10 μm in diameter, germinated in 2–4 days with an asymmetric division (Fig. 6B), then usually developed an elongate, rhizoid-like protrusion as the sporeling became 3–5 cells long (Fig. 6C) at about 6 days. By 13 days, one

Fig. 5. *Kraftia dichotoma*, ADU, holotype. A. Young cortical branches with terminal thick-walled hyaline, reflexed hairs. B. Carpogonial branch. C. Cortical filaments with a young auxiliary cell branch and floridean hairs. D. Post-fertilisation carpogonial branch with connecting filaments from cells 4 and 5. E. Semi-mature auxiliary cell branch with young lateral branches. F. Mature auxiliary cell branch with lateral branches from most cells except the auxiliary cell (number 51). G. Young carposporophyte developing from connecting filament fused to the auxiliary cell a.c.—auxiliary cell; c.f.—connecting filament; gon.—gonimoblast.

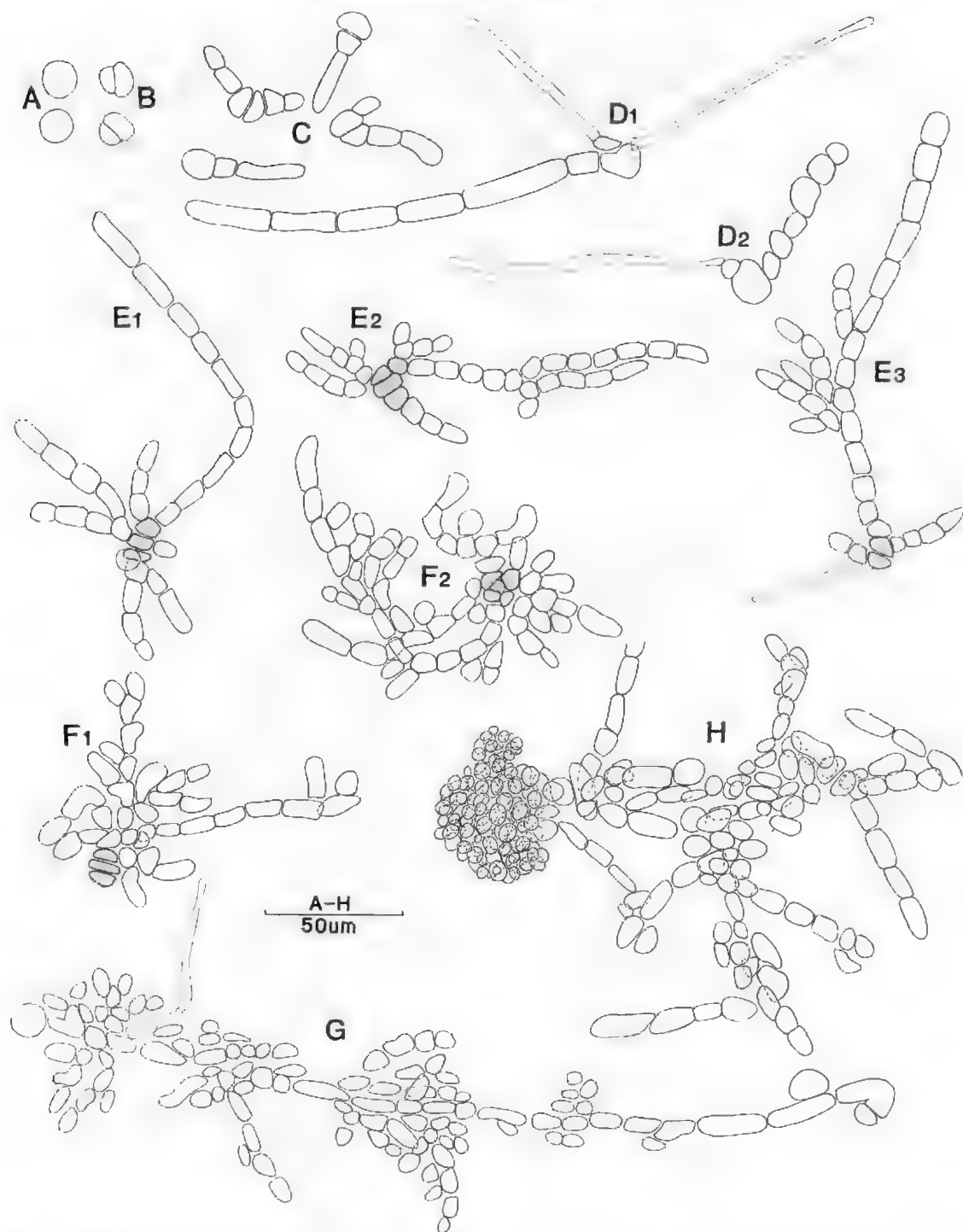


Fig. 6. *Kraftia dichotoma*. Germination stages of carpospores. A. Carpospores. B. First division of carpospores, at 2-4 days old. C. Four at 3-5 celled stage, about 6 days old. D1, D2. Sporelings with elongate rhizoids, at 13 days old. E1-E3. Sporelings with several branches, after loss of rhizoids, at 20 days old; first formed cells stippled. F1, F2. Sporelings with denser branching, some branches semi-erect, at 27 days old. G. Sporeling with a long primary filament and clusters of laterals, at 35 days old. H. Sporeling with a compact, pulvinate mass of cells, at 50 days old.

of two long rhizoidal cells were evident and the filaments were 7–10 cells long (Fig. 6D). These rhizoids were not always evident or were lost, and at 20 days several branches arose from the oldest cells or laterally from a filament in an irregular manner (Fig. 6E). By 27 days the branching was denser with semi-erect laterals and some sporclings were pseudoparenchymatous (Fig. 6F). Where a long primary filament had developed, clusters of laterals occurred along the filament by 35 days (Fig. 6G), and some of the clusters developed into fairly compact pulvinate masses several cells thick at 35–50 days (Fig. 6H). Unfortunately these cushions did not develop further though maintained for up to 80 days. The above stages were cultured on three occasions, but on no occasion showed any evidence of fertility.

Discussion

The female reproductive stages of *Krafiia* from the form and structure of the carpogonial and auxiliary cell branches to their behaviour in developing the mature carposporophytes, are so distinctively those of the Dumontiaceae that there can be little doubt that *Krafiia* belongs to this family of the Cryptonemiales.

The family Dumontiaceae has included some 15 genera, all with this characteristic female reproductive system. Of these, *Acrosiphonia*, *Cryptosiphonia* J. Agardh, *Dasyphloea*, *Dudresnaya*, *Dumontia* Lamouroux, *Parlawia* J. Agardh, *Hyalosiphonia* Okamura, *Leptocladia* J. Agardh, *Piked* Harvey and *Thuretellopsis* Kylin are uniaxial. *Constantinea* Postels & Ruprecht, *Dilsea* Stackhouse, *Neodilsea* Tokida (including *Abbottia* Perestenko 1975—see Abbott 1982), *Weeksia* Setchell, *Gibsmithia* Doty, and now *Krafiia* are multi-axial in mature thalli. Norris (1971) has shown that the young thallus of *Weeksia fryeana* is uniaxial but the apical filament later ceases growth and lateral filaments continue developing to give a secondarily multi-axial thallus. The reverse situation, where a typical multi-axial thallus is reduced to uniaxial construction, occurs in *Euthoa* in the Kallymeniaceae (Norris 1957, p. 305). Gabrielson & Hommersand (1982) advocate removal of several uniaxial genera of the Rhabdoniaceae to the multi-axial Solieriaceae in view of their reproductive similarities, and the Acrotylaceae (Krafi & Min-Thien 1983) also includes both uniaxial and multi-axial genera. However, most

families of the Cryptonemiales and Gigartinales are still characterised by either uniaxial or multi-axial construction, and Bert (1965) segregated the Dilseaceae (based on *Dilsea*) from the Dumontiaceae on this basis—i.e. Dumontiaceae for uniaxial genera and Dilseaceae for multi-axial genera.

The distinctiveness of the female reproductive system in the Dumontiaceae (*sensu lato*), which differs clearly from that of all other members of the Cryptonemiales, suggests that this arose relatively early in the evolution of this family and the uniaxial—multi-axial difference arose later. Recognition of one or two families for these genera depends on the weight given to the thallus development compared to the female reproductive system, but the distinctiveness of the latter, together with the uniaxial to multi-axial development within *Weeksia*, indicates that they are best kept within a single family, Dumontiaceae.

The family Weeksiaceae (*Weeksia*, *Constantinea* and *Leptocladia*) has been separated from the Dumontiaceae by Abbott (1968, p. 188) on the basis that while typical auxiliary cell branches occur, they are non-functional and the gonimoblast develops directly from the cell of the carpogonial branch from which connecting filaments normally develop. This appears to be a derived state and is not always so—Abbott (1968, p. 192) comments in a footnote that Norris had observed a functional auxiliary cell in *Constantinea*, and Abbott & Hollenberg (1976, p. 363) refer to the auxiliary cells in the Weeksiaceae as "sometimes functional". More recently, Lindström (1981) has shown that *Constantinea* does have functional auxiliary cells. As Bold & Wynne (1978, p. 501) note, there is little justification for recognition of the Weeksiaceae.

Most families of Cryptonemiales and Gigartinales are characterised by one method of tetrasporangium division, i.e. either zonate, tetrahedral or cruciate, though the latter two are not always clearly separated. It is unusual to find a family such as the Dumontiaceae where genera with zonate or cruciate tetrasporangia occur, though some descriptions and figures refer to these sporangia as being "irregularly" divided. Most genera of Dumontiaceae have cruciate tetrasporangia, but *Constantinea*, *Dasyphloea* and *Dudresnaya* have zonate tetrasporangia. Thus the cruciate tetrasporangia of *Dilsea* are found in several other genera of Dumontiaceae and there is no cor-

relation between tetrasporangium division and thallus construction.

Until recently, tetrasporophytes of some genera were unknown, but heteromorphy has now been established in several genera. *Aerocymphyton* (Cortel-Breeman & van den Hoek 1970) has been found to have a prostrate tetrasporophyte morphologically quite different from its erect, much branched gametophytes, *Pilea* (Scott & Dixon 1971) and *Farlowia* (DeCew & West 1981) have crustose sporophytes producing cruciate tetrasporangia, and the *Farlowia* crusts resemble those of *Haematocelis*. *Thuretellopsis* is also heteromorphic (Richardson & Dixon 1970, p. 154). Since tetrasporophytes are presently unknown in *Kraftia*, it may also be heteromorphic.

Kraftia differs in morphology from other multiaxial genera of the Dumontiaceae. *Dilsea*, *Neodilsea*, and *Weeksia* are all foliose genera, and *Constantinea* is stipitate with a peltate blade; the latter two genera are also uniaxial when juvenile. The production of laterals from the lower cells of the auxiliary cell branch and also (to a lesser extent) from the carpogonial

branch is not uncommon in genera of the Dumontiaceae, and is probably best shown in *Aerocymphyton*. *Kraftia* shows such laterals well, but they are not involved in any fusions as in *Aerocymphyton*.

Gibsmithia Doty (1963, p. 458, figs 1-17) was tentatively placed in the Dumontiaceae, and this is supported by Karam-Keriman (1976). *Gibsmithia* is multiaxial, isomorphic, forms cruciate tetrasporangia, and conforms in general with the Dumontiaceae. However, it differs in habit, vegetative structure, and detailed morphology of the carpogonial and auxiliary cell branches, and must be considered an anomalous member of the Dumontiaceae as noted by Kraft (1981, p. 22).

Acknowledgments

The second author is grateful to the Australian Research Grants Scheme for provision of Research assistance and to Research Officer Mrs E. L. Robertson for maintenance of cultures. Dr E. Gordon-Mills kindly provided the Latin diagnosis.

References

- AMORR, I. A. (1962) Morphological studies in a new species of *Aerocymphyton* (Rhodophyceae). *Amer. J. Bot.* **49**, 845-849.
- (1968) Studies in some foliose red algae of the Pacific coast. III. Dumontiaceae, *Weeksia*-ceae, Kallymeniaceae. *J. Phycol.* **4**, 180-198.
- (1982) On *Abbotia* Perstenko, 1975 (Rhodophyta). *Taxon* **31**, 300-302.
- & HOLLENBERG, C. J. (1976) "Marine Algae of California." (Stanford Univ. Press: Stanford, Calif.)
- ANAGNI, J. G. (1899) *Analecta Algologica*, Cont. V. *Upps. Univ. Arsskr.* **35**(4), 1-160, pls 1-3.
- BERT, I. J. (1965) Sur la structure et le développement de l'appareil reproducteur femelle de *Dilsea carnosa* (Schmidel) Kuntze et la position systématique du genre *Dilsea*. *Comp. Rend. Acad. Sci.* **261**, 2702-2704.
- BOLD, H. C. & WYNNE, M. J. (1978) "Introduction to the Algae—Structure and Reproduction." (Prentice-Hall: New Jersey.)
- CORTEL-BREEMAN, A. M. & VAN DEN HOEK, C. (1970) Life-history studies on Rhodophyceae I. *Aerocymphyton purpuriferum* (J. Ag.) Kyt. *Acta Bot. Neerl.* **19**, 265-284.
- CROHAN, P. J. & CROUAN, H. M. (1835) Observations microscopiques sur la genre *Mesogloia* Agardh. *Ann. Sci. Nat., Ser. 2*, **3**, 98-99, pl. 2.
- DECWE, T. C. & WEST, J. A. (1981) Investigations on the life histories of three *Farlowia* species (Rhodophyta: Cryptonemiales, Dumontiaceae) from Pacific North America. *Phycologia* **20**, 342-351.
- DE TONI, G. B. (1924) "Sylloge Algarum omnium hucusque cognitatum." Vol. 6. Floridene. (Padua.)
- DOTY, M. S. (1963) *Gibsmithia hawaiiensis* gen. nov. et sp. n. *Puif. Sci.* **17**, 453-465.
- DUCKER, S. C., FOORD, N. J. & KNOX, R. B. (1977) Biology of Australian Seagrasses: the genus *Amphibolis* C. Agardh (Cymodoceaceae). *Aust. J. Bot.* **25**, 67-95.
- FISHMAN, N. J. & NORRIS, J. N. (1981) *Dudresnaya patula* sp. nov., an unusual deep-water red alga from Florida. *J. Phycol.* **17**, 186-191.
- GABRIELSON, P. W. & HOMMERSAND, M. H. (1982) The Atlantic species of *Solieria* (Gigartinales, Rhodophyta): Their morphology, distribution and affinities. *Ibid.* **18**, 13-45.
- HARVEY, W. H. (1855) Some account of the marine botany of the colony of Western Australia. *Trans. R. Irish Acad.* **22**, 525-566.
- HAWKES, M. W. (1982) *Aerocymphyton firmum* sp. nov. (Rhodophyta, Cryptonemiales), a new subtidal red alga from New Zealand: developmental morphology and distribution of the gametophyte. *J. Phycol.* **18**, 447-454.
- HOWE, M. A. (1914) The marine algae of Peru. *Mem. Torrey Bot. Club* **15**, 1-185, pls 1-66.
- KARAM-KERIMAN, T. B. (1976) Structure, reproduction et discussion sur la position systématique du genre *Gibsmithia* (Rhodophyceae). *Bull. Mus. Nat. Hist. Nat.* **365**, 21-32.
- KRAFT, G. T. (1981) Rhodophyta: Morphology and Classification. In Lobban, C. S. & Wynne, M. J. (Eds), "The Biology of Seaweeds", Ch. 1, pp. 6-51. *Bot. Monogr.* Vol. 17. (Blackwell: Oxford.)

- KRAFT, G. T. & MIN-THEIN, U. (1983) *Clavicornium* and *Antrocentrum*, two new genera of Acrotylaceae (Gigartinales, Rhodophyta) from southern Australia. *Phycologia* **22**(2), 171-183.
- KYLIN, H. (1956) "Die Gattungen der Rhodophyceen". (Gleerups: Lund.)
- LINDSTROM, S. (1981) Female reproductive structures and strategy in a red alga, *Constantinea rosa-marina* (Gmelin) Postels et Ruprecht (Dumontiaceae, Cryptonemiales). *Jap. J. Phycol.* **29**, 251-257.
- LITTLER, M. M. (1974) The structure and reproduction of *Dudresnaya lubrica* sp. nov. (Rhodophyta, Dumontiaceae). *Br. phycol. J.* **9**, 149-156.
- MITCHELL, E. A. (1966) The southern Australian genera of the Dumontiaceae (Rhodophyta). *Nova Hedwigia* **11**, 209-220, pls 22-26.
- MONTAGNE, C. (1842) "Prodromus generum specierumque phycearum novarum in itinere Antarcticum". (Paris.)
- (1845) "Voyage au Pôle Sud et dans l'Océanie sur les Corvettes l'Astrolabe et la Zélée. I. Botanique. T.I. (Paris.)
- NERRIS, R. E. (1957) Morphological studies on the Kallymeniaceae. *Univ. Calif. Publ. Bot.* **28**, 251-333.
- (1971) Development of the foliose thallus of *Weeksia fryeana* (Rhodophyceae). *Phycologia* **10**, 205-213.
- PAPENFUSS, G. F. (1958) Notes on algal nomenclature IV. *Taxon* **7**, 104-109.
- PERESTENKO, L. P. (1975). The red algae of the far-eastern seas of the U.S.S.R. Foliose cryptonemiacean algae (Cryptonemiales, Rhodophyta). *Bot. Zh.* **60**, 1676-1689.
- RICHARDSON, N. & DIXON, P. S. (1970) Culture studies on *Thuretellopsis peggiana* Kylin. *J. Phycol.* **6**, 154-159.
- SCOTT, J. L. & DIXON, P. S. (1971) The life history of *Pikea californica* Harv. *Ibid.* **7**, 295-300.
- SETCHELL, W. A. (1912) *Algae Novae et minus Cognitae I.* *Univ. Calif. Publ. Bot.* **4**, 229-269.
- SJOSTEDT, L. G. (1926) Floridean Studies. *Lunds Univ. Arsskr.*, N.F. Avd 2, **22**(4), 1-95.
- SONDER, O. G. (1853) *Plantae Muellerianae*, *Algae. Linnaea* **25**, 657-709.
- (1981) *Algae Australianae hactenus cognitae.* In F. Mueller, "Fragmenta Phytographiae Australiae", Vol. 11, Suppl. pp. 1-132. (Melbourne.)
- TAYLOR, W. R. (1952) Reproduction of *Acrosymphyton caribaeum*. *Pap. Mich. Acad. Sci. Arts Lett.* **36**, 31-37, pls 1-3.
- WILSON, J. B. (1982) Catalogue of algae collected at or near Port Phillip Heads and Western Port. *Proc. R. Soc. Vic.* N.S. **4**, 157-190.
- WOMERSLEY, H. B. S. (1981) Aspects of the distribution and biology of Australian marine macro-algae. In Pate, J. S. & McComb, A. J. (Eds), "The Biology of Australian Plants," Ch. 10, pp. 294-306. (Univ. W. Aust. Press: Perth.)
- (1983) "The marine benthic flora of southern Australia". Part I. (Govt. Printer: Adelaide.)

LUNETTES OF LAKE EYRE NORTH, SOUTH AUSTRALIA

BY J. A. DULHUNTY

Summary

Large lunettes, from 30 to 48 m high and 1 to 2.5 km wide, occur along the lee shores of Lake Eyre North, from Koorakarina Creek in the northwest to Cooper Creek in the northeast. They consist of large, deeply eroded cores or bases of semi-consolidated sand, and small, scattered, active crests of loose sand. They probably formed during an arid phase which dried up and deflated sediments into the Simpson and Tirari Deserts, from the bed of Lake Dieri – the late Pleistocene ancestor of Lake Eyre. Subsequently, in Holocene time, deflation waned and erosion of the lunettes commenced as a less arid climate initiated ephemeral sedimentation in Lake Eyre limiting source material to river-flood sediments. Longitudinal sandridges of the Simpson Desert form on the northern downwind side of the lunettes.

LUNETTES OF LAKE EYRE NORTH, SOUTH AUSTRALIA

by J. A. DULHUNTY*

Summary

DULHUNTY, J. A. (1983) Lunettes of Lake Eyre North, South Australia, *Trans. R. Soc. S. Aust.* **107**(4), 219-222, 30 November, 1983.

Large lunettes, from 30 to 48 m high and 1 to 2.5 km wide, occur along the lee shores of Lake Eyre North, from Koorakarina Creek in the northwest to Cooper Creek in the northeast. They consist of large, deeply eroded cores or bases of semi-consolidated sand, and small, scattered, active crests of loose sand. They probably formed during an arid phase which dried up and deflated sediments into the Simpson and Tirari Deserts, from the bed of Lake Dieri—the late Pleistocene ancestor of Lake Eyre. Subsequently, in Holocene time, deflation waned and erosion of the lunettes commenced as a less arid climate initiated ephemeral sedimentation in Lake Eyre limiting source material to river-flood sediments. Longitudinal sandridges of the Simpson Desert form on the northern downwind side of the lunettes.

KEY WORDS: Lake Eyre North, lunettes, sandridges.

Introduction

During 1979 and 1980, expeditions to the northern and northeastern shores of Lake Eyre North were undertaken to investigate features observed during earlier aerial reconnaissance. In 1979 access to the northwest corner of the lake was gained by four-wheel-drive vehicles from William Creek, through Anna Creek Station to the Koorakarina-Anchor Creek Estuary. From there to the Warburton Estuary the shore was investigated using balloon-tyred, Honda ATC 90 motor triecycles. In 1980 Honda triecycles were used to travel north along the eastern shore of the lake from the Frome-Clayton Estuary to Cooper Creek, and then along the northeastern shore to the Warburton Estuary.

The purpose of this paper is to record the occurrence, distribution and general nature of large sand mounds at the northern end of Lake Eyre North. They follow closely the lake shoreline between Koorakarina Creek in the northwest and Cooper Creek in the northeast. This is the lee shore in relation to the resultant direction of prevailing, strong winds which have determined the directional trend of parallel longitudinal sandridges of the Simpson and Tirari Deserts, in areas immediately north and east of Lake Eyre North (Bowler 1976, Brookfield 1970, King 1960, Twidale 1972). The sand mounds are similar in general features to those described by Twidale (1972) as leeside mounds and by Bowler (1976) as transverse, lakeshore dunes in other Australian arid

regions. They are also equivalent to the clay and sand dunes or lunettes of semi-arid regions (Coffey 1909, Hills 1940, Stephens & Crocker 1946, Balaïne 1954, Campbell 1968, Wopfner & Twidale 1967). It is proposed for the purpose of this paper, to use the term lunettes in referring to the sand mounds along the lee shore of Lake Eyre North.

Large lunettes as described here, occur only on the lee shores at the northern end of Lake Eyre North, and have not been found on any other shorelines of the north lake. King (1956) examined longitudinal sandridges near the southeast corner of Lake Eyre North but did not describe any lunette-type features. Twidale (1972) described leeside, debris mounds along the shores of Lake Eyre South, immediately north of the estuary of Warriners Creek and the Marguarite. He also referred in general to leeside mounds on the northern sides of many playas in the vicinity of Lake Eyre, but did not describe any lunettes or leeside mounds in particular bordering Lake Eyre North.

Shoreline lunettes

Large lunettes occur along the lee shoreline at the northern end of Lake Eyre North (Fig. 1). They follow closely the trends and irregularities of the lee shoreline, forming a continuous dune system for 110 km, broken only by the Warburton and Kalaweerina Estuaries which are less than 1 km wide. Along most of the shore there is only one continuous lunette with a gently sloping apron, up to 1 km wide, running down to the shoreline of the lake. At one place immediately east of the

* Department of Geology and Geophysics, University of Sydney, N.S.W., 2006.

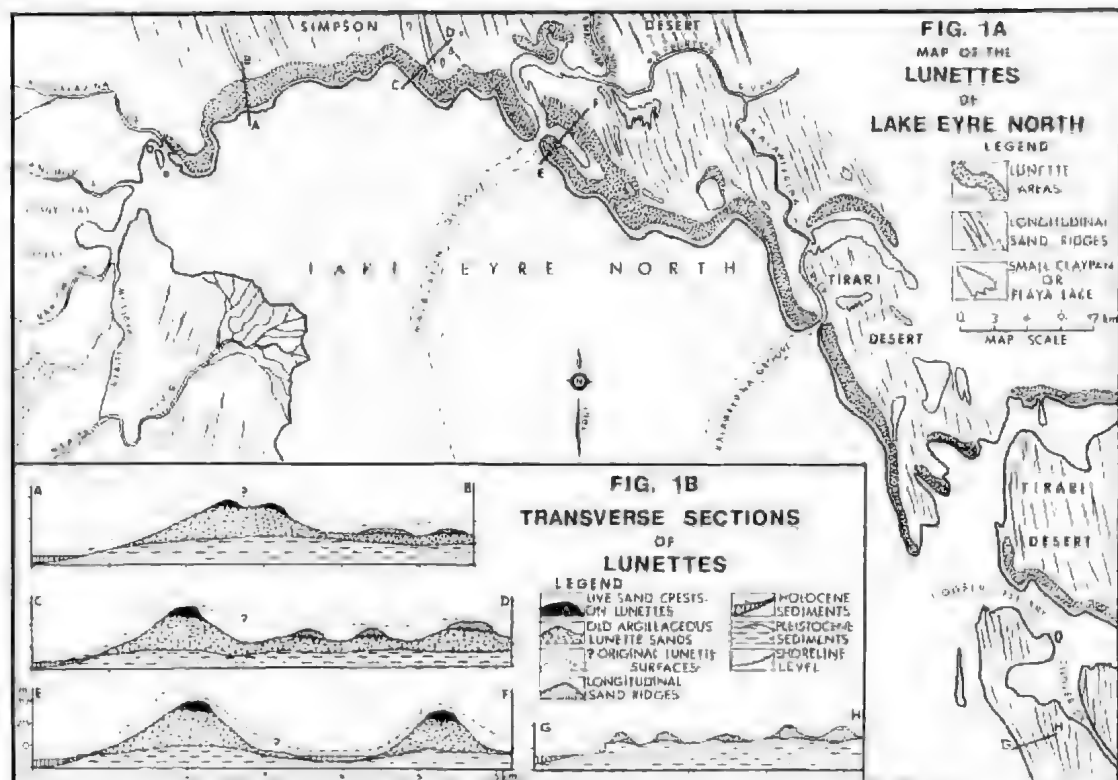


Fig. 1. Lunettes along the northern shores of Lake Eyre North.

Warburton Estuary (Fig. 1, Sect. E-F) there is a second lunette almost 2 km wide which is east of but parallel to the main shoreline lunette. They are separated by a backwater playa of the Warburton River, however, further southeast they unite to form a single shoreline lunette. Elsewhere, small claypans or river floodout areas close to the main shoreline lunette, have isolated lunettes on their lee sides.

The main shoreline lunettes are between 1.5 and 3 km wide, rising to an average height of about 30 m above the lake bed, although some are 40 m high and the highest measured was 48 m. They are complex in structure, having large, pale yellow-brown, semi-consolidated cores or bases and relatively small, scattered, active crests of pale yellow-white sand (Fig. 1B). The crests are quite friable with less than 1.0% clay, but the cores are firmer with between 1.0 and 4.0% clay. Both are essentially sand lunettes.

The large cores have been extensively eroded and the small active crests lie disconformably upon their eroded surfaces (Fig. 1B). The

bases appear to be erosional residuals of old, large lunettes formed during an earlier, arid phase by transport of sand and some clay to a lee shore of Lake Dieri, the late Pleistocene ancestor of Lake Eyre (Dulhunty 1982, David & Browne 1950, Löffler & Sullivan 1979, Bowler 1973, Wopner & Twidale 1967). The active crests appear to be a second generation of younger features functioning as lunettes to the present day lake. At some stage after maximum development of the first generation of lunettes, the rate of supply of source material decreased and the lunettes were eroded, reduced in size and modified in shape. This is illustrated in Figure 1B by broken lines which are entirely speculative and diagrammatic, intended only to give some idea of the amount of erosion and change of shape suggested by field studies.

Decrease in supply of source material and erosion of the lunettes might have been due to a wetter, climatic phase following the late Pleistocene-early Holocene arid phase (Bowler 1976) which elevated the watertable and initiated ephemeral Lake Eyre sedimentation

on the eroded surface of the old Dieri lake bed (Dulhunty 1982). This retarded deflation and held river-sediments as Holocene beds in Lake Eyre, which has continued to the present day.

Field observations over seven years, during and following the major 1974 filling of Lake Eyre, revealed the formation of extensive, but very low-profile deltas of fine white sand near estuaries of the northern rivers. Silt and clay were deposited widely over the playa environment at the northern end of the lake (Dulhunty 1982). At places, small shoreline banks of sand, silt and clay were formed along lee shores by wind-wave transport. The lake dried up between 1978 and 1981, and the highly elevated watertable returned slowly towards its normal, long-term average level. Sediments commenced deflating and were still doing so at the end of 1982. Sand from deltas near the estuaries of the northern rivers blew downwind over the eroded surfaces of the old lunette bases and up onto the active crests. Silt and clay deposited in the playa environment, dried at the surface as the watertable fell, and deflated over the lunettes into the Simpson Desert. Small amounts of sand from the wave-built shoreline banks were also blown onto the lunette crests, while silt and clay were carried into the desert.

Along most of the northern (lee) sides of the lunettes, sand moves down from the active crests into a narrow confused area up to 2 km wide, where the longitudinal sandridges of the Simpson Desert commence. At some places there is no confused area and the longitudinal sandridges commence on the lee slopes of the lunettes.

As the lake bed is tilted to the south, relatively shallow-water conditions occur along

northern shores during major fillings. This helps promote wave transport of sediments to the lee shore, but reduces wave height and wave erosions of old lunette cores, the presence of which close to the shore suggests neither advance nor retreat of the shoreline since the lunettes were formed.

South of the Cooper Estuary along the eastern shore (Fig. 1), well-formed lunettes are replaced by a different shoreline regime. The general trends of the shore and longitudinal sandridges (and hence prevailing winds) are very similar. This means that only limited amounts of sand, silt and clay are blown ashore by deflation of sediments from the lake bed after major fillings. Also water depths, during fillings, are greater than across the northern and northeastern shores, and pronounced erosion by wave action has led to eastern migration of the shoreline. Consequently, any small shoreline lunettes which might have formed at the same time as the large bases of the northern shoreline lunettes, have been completely eroded away. Small amounts of sand blown in from the present lake bed, are added directly to the live crests of the longitudinal sandridges.

Acknowledgments

It is wished to acknowledge (i) valuable discussion with Drs J. M. Bowler and R. J. Wasson of the Australian National University, Canberra; (ii) valuable assistance of Muloorina and Anna Creek Stations in conducting the 1979 and 1980 expeditions and (iii) research facilities provided by the Department of Geology and Geophysics, University of Sydney.

References

- BOULANGER, J. (1954) La sebkhia de Bien Ziane et sa "lunette" ou bourrelet. *Rev. de Geom. Dynamique* 5, 102-122.
- BOWLER, J. M. (1973) Clay dunes: their occurrence, formation and environmental significance. *Earth Sci. Rev.* 9, 315-338.
- (1976) Aridity in Australia: age, origins and expression in aeolian landforms and sediments. *Ibid.* 12, 279-310.
- BROOKFIELD, M. (1970) Dune trends and wind regime in Central Australia. *Z. Geomorphol.* 10, 121-153.
- CAMPBELL, E. M. (1968) Lunettes in southern South Australia. *Trans. R. Soc. S. Aust.* 92, 85-109.
- COFFEY, G. N. (1909) Clay dunes. *J. geol.* 17, 754-755.
- DAVID, T. W. R. & BROWN, W. R. (1950) 'The geology of the Commonwealth of Australia'. (Arnold: London.)
- DULHUNTY, J. A. (1981) Quaternary sedimentary environments in the Lake Eyre region, South Australia. *Geol. Soc. Aust.*, Abstract Volume No. 3, 57-58.
- (1982) Holocene sedimentary environments in Lake Eyre, South Australia. *J. Geol. Soc. Aust.* 29, 437-442.
- HILLIS, P. S. (1940) The lunette, a new landform of aeolian origin. *Aust. Geogr.* 3, 15-21.
- KING, D. (1956) The Quaternary stratigraphic record at Lake Eyre North and the evolution of existing topographic forms. *Trans. R. Soc. S. Aust.* 79, 93-103.

- (1960) The sandridge deserts of South Australia and related aeolian landforms of the Quaternary arid cycles. *Ibid.* **83**, 99-108.
- LOFFLER, E. & SULLIVAN, M. E. (1979) Lake Dieri resurrected: an interpretation using satellite imagery. *Z. Geomorphol.* **23**, 233-242.
- STEPHENS, C. G. & CROCKER, R. L. (1946) Composition and genesis of lunettes. *Trans. R. Soc. S. Aust.* **70**, 302-312.
- TWIDALE, C. R. (1972) Landform development in the Lake Eyre region, Australia. *Geogr. Rev.* **62**, 40-70.
- (1976) "Analysis of Landforms". (John Wiley & Sons Australia Pty Ltd: Sydney.) pp. 313-314.
- WOPFNER, H. & TWIDALE, C. R. (1967) Geomorphological history of the Lake Eyre Basin. In J. N. Jennings & J. A. Mabbutt (Eds) "Landform studies from Australia and New Guinea." (A.N.U. Press: Canberra.) pp. 118-143.

SOME FRESHWATER CHLOROPHYTA FROM THE BOOL LAGOON SYSTEM IN SOUTH-EASTERN SOUTH AUSTRALIA

BY S. SKINNER

Summary

Nine taxa of freshwater benthic and planktonic Chlorophyta are recorded from the alkaline waters of the Bool Lagoon system, including a form of *Enteromorpha clathrata*, and five members of the Zygnemales including a new species of *Mougeotia* here described as *M. sesterisignifera* sp. nov.

SOME FRESHWATER CHLOROPHYTA FROM THE BOOL LAGOON SYSTEM IN SOUTH-EASTERN SOUTH AUSTRALIA

by S. SKINNER*

Summary

SKINNER, S. (1983) Some freshwater Chlorophyta from the Bool Lagoon system in south-eastern South Australia. *Trans. R. Soc. S. Aust.* **107**(4), 223-229, 30 November, 1983.

Nine taxa of freshwater benthic and planktonic Chlorophyta are recorded from the alkaline waters of the Bool Lagoon system, including a form of *Enteromorpha clathrata*, and five members of the Zygnematales including a new species of *Mougeotia* here described as *M. sesterlsignifera* sp. nov.

KEY WORDS: Chlorophyta, freshwater algae; Bool Lagoon; South Australia.

Introduction

Many of the inland waterways of South Australia contain hard water with alkaline pH and high levels of dissolved bicarbonates. The only taxonomic record of freshwater Chlorophyta from this state is that of Prescott & Scott (1952) on desmid collections of Ivan Ophel from Kangaroo Island and Mt Compass, areas noted for their acid soils and water.

The Bool Lagoon system in the upper south-east of South Australia is an important wildlife refuge and conservation park. It is a hard water lagoon system of several permanent and numerous transient shallow lakes fed by Mosquito Creek. The water is alkaline, having an average pH of 8.5 and a dissolved bicarbonate concentration of $7.5 \text{ meq.l}^{-1} \text{ HCO}_3^-$ (Walker *et al.* 1982).¹

Methods

Samples of floating mats of algae were obtained during a recent flora and fauna survey of the Bool Lagoon Game Reserve and Hacks Lagoon Conservation Park, from each of eight stations selected to demonstrate the diversity of habitats in the system, and one further sample from near the ibis rookery on Bool Lagoon later in the same year. The Chlorophyta from these samples are described and illustrated here. Other taxa, including numerous diatoms, a species of *Cladophora* (insufficient material for identification) and charophytes were encountered. Specimens are held in the algal herbarium at the University of Adelaide (ADU).

The Zygnematales were verified from Kolkwitz and Krieger (1941) and the Oedogoniales from Gautier-Liévre (1963, 1964). The

ordinal classification is that of Bold and Wynne (1978).

CHLOROPHYTA, CHLORELLALES

Scenedesmus quadricaudus (Turp.) Bréb. var. *quadricaudus* May 1973: 445.

FIG. 1A

Thallus a coenobium of four cells in slightly alternate series, truncated ellipsoid in shape, $6-10 \mu\text{m}$ in diameter, L/B 2.5-3, attached for at least the middle two thirds of long sides; both end cells with an outward pointing curved spine from cell wall of each short side. Collected at Station 1, ibis rookery, Bool Lagoon (Roberts and Preece, 5.xi.1982; ADU, A53988). A common member of the phytoplankton in many parts of Australia. Cosmopolitan.

ULVALES

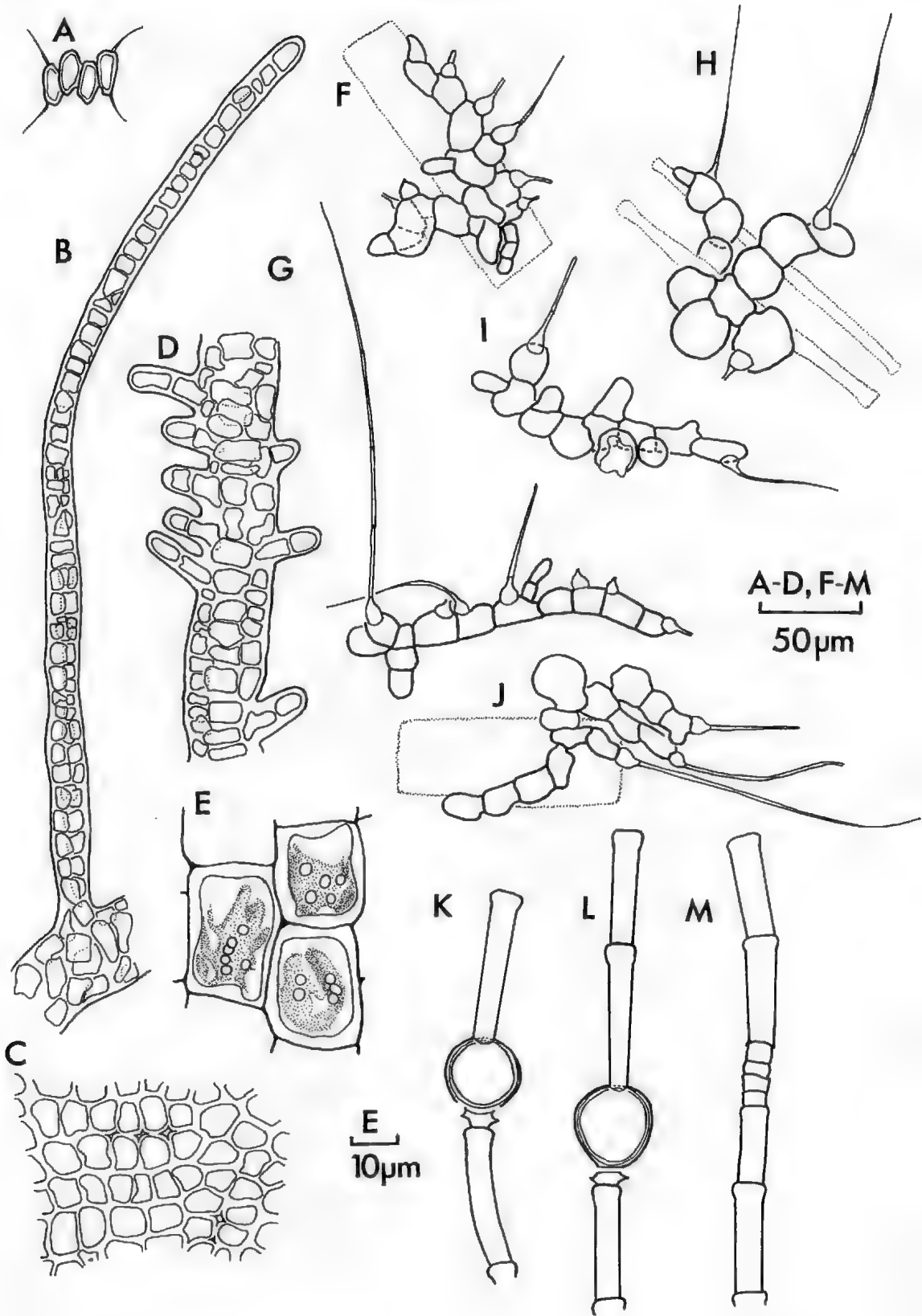
Enteromorpha clathrata (Roth) Greville. Bliding, 1963: 107. forma.

FIG. 1, B-E

Thallus a much-branched tubular system of small, more or less isodiametric cells in ordered ranks—the ordering becoming less regular in older and wider parts of thallus—surrounding a hollow centre, attached or free floating; thalli $(0.1)0.5-4.0(10.0) \text{ mm}$ in diameter, to 50 mm or greater in length, light green to green, often encrusted with lime. Cells thick walled $10-18 \mu\text{m}$ in diameter, L/B 0.5-1.5, with one lobed laminate chloroplast often occupying only part of the cell

¹Walker, K. F., Balla, S. A., Lloyd, L. N., Moller, J. C. & Pollard, S. J. (1982), Fish and aquatic invertebrates of Bool Lagoon Game Reserve and Hacks Lagoon Conservation Park. Report submitted to South Australian Department of Environment and Planning.

* Department of Botany, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001.



(Fig. 1.E) and numerous 2–6(8) small pyrenoids. Lateral branches arising irregularly from the body of the main thallus, at first uniseriate but becoming multiseriate and tubular 30 cells or less from tip. No undisputed reproductive areas found.

Collected at Station 1, ibis rookery, Bool Lagoon (Roberts and Preece, 5.xi.1982; ADU A53986).

Enteromorpha species are not uncommon in alkaline or brackish inland waters in South Australia. Older records (Hardy 1906) list *E. intestinalis* Link. for inland waters in Victoria. These records should be reviewed in the light of more recent taxonomic studies of the genus.

CHAETOPHORALES

Aplanochaete confervicola (Naeg. ex Kuetz.) Rabenh. Tupa 1974: 83, figs 13, 14.

A. repens A. Braun. Bailey 1898: 7. Prescott 1951: 125, Pl. 17, Figs 2, 3.

FIG. 1, F-J

Small proliferating decumbent epiphyte, with occasional erect cells, adnate to the cell wall of various other filamentous chlorophytes, and diatoms, 160–200 μm between extremities. Cells cylindrical to subglobose, with flattened base, 10–18(–20) μm in diameter, L/B 1–2(–2.5), with one large chloroplast with one pyrenoid; most if not all mature cells surmounted by naked seta or hair cell up to 180 μm long, usually broken off near base, with a bulbous base and a septum at the top of bulb. Sporangial cells inflated globose and often erect from filament, 30 μm in diameter, opening by rupture.

Collected at Station 1, ibis rookery, Bool Lagoon (Roberts and Preece, 5.xi.1982; ADU; 53985), on *Zygnema*, *Spirogyra*, *Mougeotia*, loose vegetable fragments and a diatom. Cosmopolitan.

A species of *Coleochaete* was also encountered on cells of *Chara* at Station 3, east Big Hill, Bool Lagoon (Lloyd, 15.ix.1982) but was not fertile.

OEDOGONIALES

Oedogonium infirmum Tiffany 1924:

183, Pl. II, figs 6–9; 1930: 101, Pl XXXIII, figs 289–292. Gautier-Lièvre 1963: Pl 89, figs 148 a-c. Gautier-Lièvre 1964: 424.

FIG. 1, K-M

Filaments narrow, cells 15–18 μm broad, L/B 5–8, terminally capitellate, partly or wholly lime encrusted; basal attachment a simple bulb; uppermost cells absent in samples. Macrandrous, dioecious; male segments in fours to eights (to tens), simple, L/B 1, two spermatozoa per segment; oogonium subspherical to spherical, without a modified supporting cell, single, 38–42 μm in diameter, opening by a wide basal structure; spore smooth-walled, spherical, orange brown, filling the oogonium, 38–40 μm diam.

Collected at Station 1, ibis rookery (Roberts and Preece, 5.xi.1982); Station 7, north lagoon (Lloyd, 5.ix.1982; ADU, A53987). U.S.A. and Algeria.

This taxon agrees very well with the description given by Tiffany (1924).

There were one or two further species of *Oedogonium* and a species of *Bulbochaete* present but these were not fertile and not able to be further identified.

ZYGNEMALES

Mougeotia sestertisignifera sp. nov.

FIG. 2, A-C

Filaments unbranched, broad; cells 22–26 μm in diameter, 70–200 μm long, cellular fluid clear, end wall lenticular; single broad laminar chloroplast with a central isthmus, crenulate margins and (4)5–10 scattered prominent pyrenoids; nucleus central to slightly displaced, in plane of chloroplast.

Conjugation scalariform; zygospore H-shaped, with a broad conjugation tube and arms extending to almost fill both gametangial cells, 60–80 μm in median diameter, outer wall smooth, mesospore laminate, golden.

Type locality: Bool Lagoon, S. Aust.

Type: Ibis rookery (Station 1), free floating (Roberts and Preece, 5.xi.1982; ADU, A53993) also (Lloyd, 15.ix.1982; vegetative filaments only).

Diagnosis: Cellulac 22–26 μm late atque 70–200 μm longae, chloroplastis laminatis cum multis pyrenoidibus dispulsis; coniugatio scalariformis, zygospora sestertisigniforma 60–80 μm late in medio, mesospora laminate, auraria.

Fig. 1. A. *Scenedesmus quadricaudus* var. *quadricaudus*. B-E. *Enteromorpha clathrata* forma. B. Developing lateral branch. C. mature thallus, part, surface view. D. Young thallus with lateral initials. E. Vegetative cells with chloroplast and pyrenoids. F-J. *Aplanochaete confervicola*. K-M. *Oedogonium infirmum*. K, L. Oospores in oogonia. M. male filament.

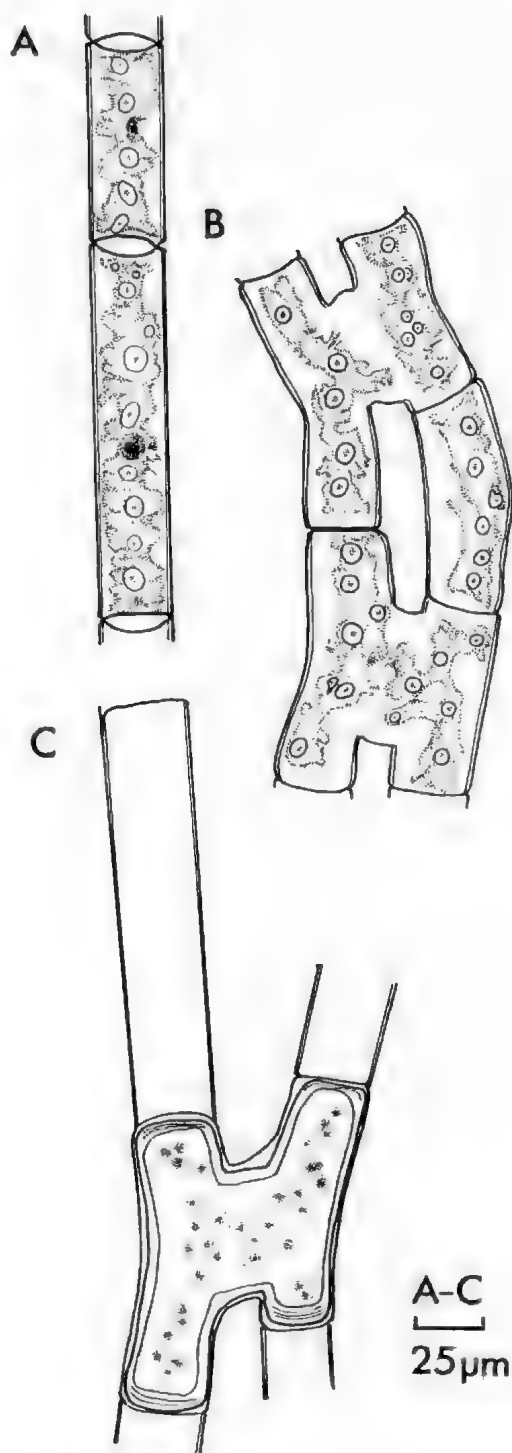


Fig. 2. A-C, *Mougeotia virescens* forma. A. Vegetative cells. B. Conjugating cells. C. Zygospore.

With its H-shaped spore this taxon is similar to members of the genus *Temnogrametum* but does not appear to have specialized smaller gametangial cells, nor does its spore show a sigmoid process described for several species in that genus. In vegetative form, although the cells are broader, this taxon comes close to the group of *Mougeotia* species which show quadrate spores, especially *M. virescens* (Hass.) Borge as described by Kolkwitz and Krieger (1941) and Prescott (1951). The specific epithet is chosen from the latin sign for a sestertius, two linked I's.

Zygnema carteri

Czurda 1932: 114, Kolkwitz & Krieger 1941: 223. *Zygnema pectinatum* (Vauch.) Ag. var. *decursum* (Vauch.) Kirchn. sensu Carter 1924: 62; figs II, I.

FIG. 3 A-C

Filaments narrow; cells (10-)12-16(-18) μm in diameter, L/B 6-10(12). End wall lenticular; two stellate chloroplasts each with a large pyrenoid, close to the central nucleus.

Conjugation scleraform; gametangial tube incomplete, zygospore held in mucilage between gametangial cells; zygospore spherical, pale golden, mesospore scorbiculate, 26-30 μm in diameter.

Collected at Station 8, Haeks Lagoon (Lloyd, 15.ix.1982: ADU, A53989), New Caledonia.

This taxon keys to *Z. carteri* in Kolkwitz & Krieger (1941), but does not fit the description there or in Czurda (1932) perfectly; no lateral conjugation was found in the Haeks Lagoon material, and the incomplete gametangial tube and envelope of mucilage are not mentioned in the original descriptions.

There was at least one further species of *Zygnema* present in the samples, but not in a fertile state.

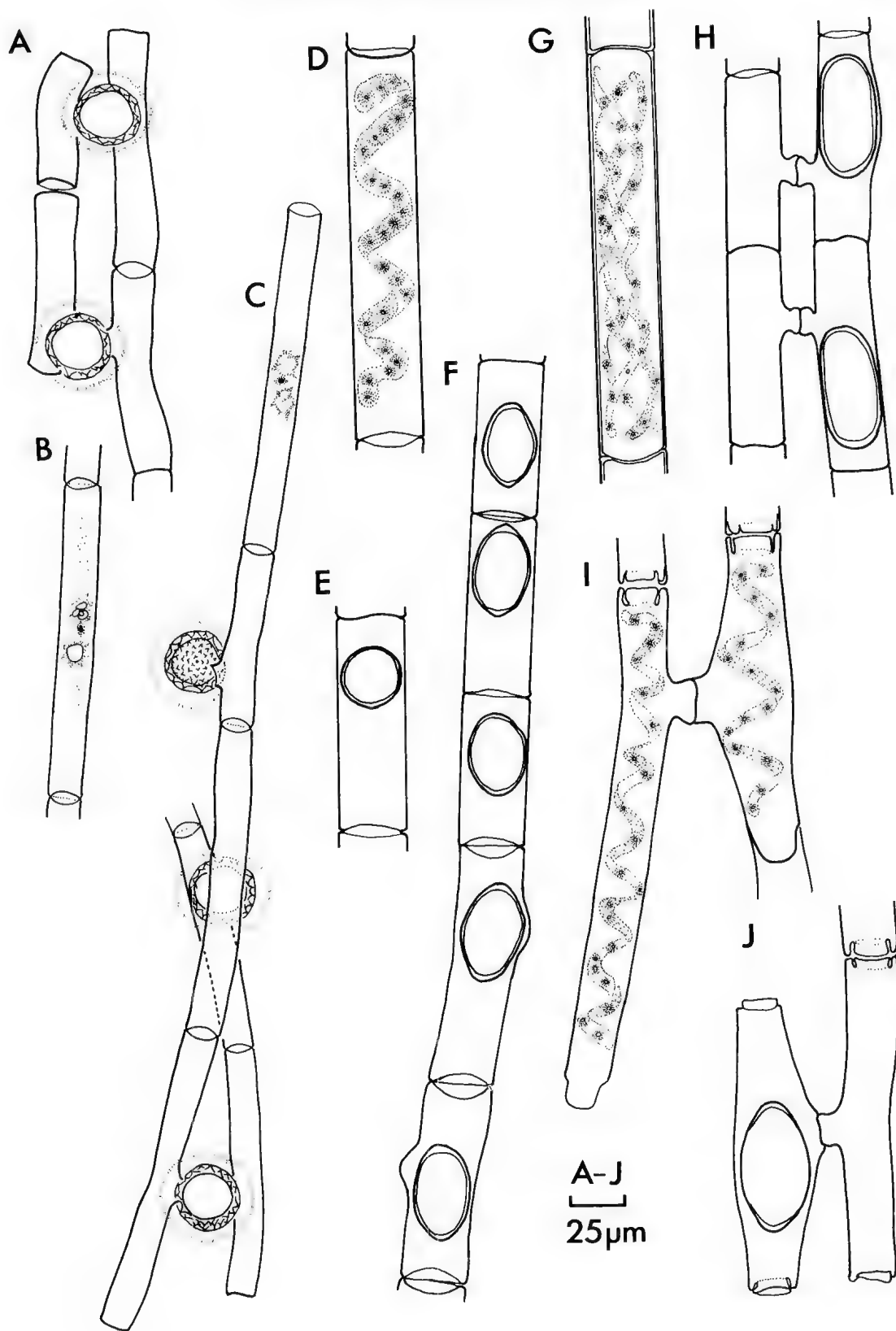
Spirogyra mirabilis (Hass.)

Kuetzing, Kolkwitz & Krieger 1941: 426, figs 672, 673.

FIGS 3D-F

Filaments moderately broad; cells 28-32 μm in diameter, L/B 2.5-7, end wall lenticular; single chloroplast of 4-8 turns, with numerous large pyrenoids; nucleus central, stellate.

Aplanospores (parthenospores?) in series, spherical to ellipsoid, smooth walled, golden mesospore 28-34 \times 28-45 μm ; sporangial cell



wall sometimes with an arrested gametangial tube.

Collected at Station 8, Hacks Lagoon (Lloyd, 15.ix.1982; ADU, A53992). Also known in South Australia from the Onkaparinga River, Old Noarlunga, ford (Skinner and Thomas, 14.x.1977, ADU, A48586). Cosmopolitan.

Spirogyra irregularis Naegeli.

Kolkwitz & Krieger, 1941: 349, fig. 486.

FIG. 3G, H

Filaments moderately broad; cells 24–30 μm in diameter, L/B 2–8, end wall lenticular; chloroplasts 2–3, of 3–7 turns, with numerous pyrenoids; nucleus central stellate.

Conjugation scalariform, gametangial tubes cup-shaped and of almost equal halves, often disposed away from the centre of the cells; neither gametangial cell inflated; zygospore smooth, slightly compressed ovoid, dark yellow-brown, 30 \times 75–85(90) μm .

Collected at Station 1, ibis rookery, Bool Lagoon (Lloyd, 15.ix.1982; ADU, A53991). Cosmopolitan.

Spirogyra frigida Gay.

Kolkwitz & Krieger 1941: 448, fig. 719.

FIG. 3 I, J

Filaments narrow; cells (16) 18–23 μm in diameter, L/B 4–10; end wall replicate; chloroplast single, of 5–9 turns, with numerous pyrenoids; nucleus stellate, central.

Conjugate scalariform: gametangial tube almost cylindrical, unequal, acceptor cell inflated towards the gametangial tube; zygospore elliptical, smooth-walled, pale brown, 35 \times 70–75 μm .

Collected at Station 1, ibis rookery, Bool Lagoon (Lloyd, 15.ix.1982; ADU, A53990). Station, 8, Hacks Lagoon (Lloyd, 15.ix.1982). Cosmopolitan.

This species is very close to the even more widespread *S. inflata* (Vaucher) Kuetzing

from which it differs by not showing lateral conjugation (Kolkwitz & Krieger 1941).

There were three other species of *Spirogyra* in the samples but they were not fertile and could not be identified.

Only one desmid, a very small species of *Euastrum* or *Cosmarium*, was found in the samples.

Key to *Spirogyra* species.

1. Aplanospores formed, arrested gametangial tube sometimes present
..... *Spirogyra mirabilis*
Zygospores formed, Gametangial tube not arrested, always present 2
2. Vegetative cells 24–30 μm in diameter, end wall lenticular; chloroplasts 2–3, of 3–7 turns; acceptor cells cylindrical or nearly so, gametangial tubes equal *Spirogyra irregularis*
Vegetative cells 18–23 μm in diameter, end wall replicate; chloroplast single, of 5–9 turns; acceptor cells inflated gametangial tubes unequal
..... *Spirogyra frigida*

Discussion

This paper records the presence of a small number of Chlorophyta from the Bool Lagoon system. It is based on only two sets of collections, and indicates that there is much yet to be learned about the algae of this system. A more complete list of species and their distributions must await further collections. Comparison with other inland aquatic systems in south-eastern South Australia and adjacent areas of Victoria is not possible because no published lists are available.

Acknowledgments

Thanks are due to Dr K. F. Walker and his students, particularly Lance Lloyd, for providing the initial collections and information on water chemistry, and to Misses J. Roberts and K. Preece for the later sample from the ibis rookery.

References

- BAILEY, F. M. (1898) Contributions to the Queensland Flora. *Botany Bull.* No. 15, 1–34.
HEDING, C. (1963) A critical survey of European taxa in Ulvales. Part 1. *Capsosiphon*, *Percursaria*, *Blidingia*, *Entertomorpha*. *Opera Botanica*, 8(3): 1–160.
BOLD, H. C. & WYNNE, M. J. (1978) *Introduction to the Algae. Structure and Reproduction* (Prentice-Hall, Inc.: New Jersey).
CARTER, N. (1924) Freshwater Algae. In "Plants from New Caledonia". *J. Linn. Soc. Bot.* 44: 47–68.

Fig. 3. A–C, *Zygnema carteri*. A, C. Filaments showing scalariform conjugation with zygospores. B. Vegetative cell. D–F, *Spirogyra mirabilis*. D. Vegetative cell. E. Cell with spherical aplanospore. F. Filament with ovoid and ellipsoid aplanospores. G–H, *Spirogyra irregularis*. G. Vegetative cell. H. Filaments showing scalariform conjugation and zygospores. I, J, *Spirogyra frigida*. I. Fragment of filament showing conjugation cells in vegetative state prior to gamete transfer. J. Zygospore and conjugation cells.

- CZURDA, V. (1932) Zygnemales Vol. 9. In A. Pascher *Die Süßwasserflora von mitteleuropas* (Gustav Fisher: Jena).
- GAUTIER-LIEVRE, L. (1963) Oedogoniacées Africains. *Nova Hedw.* **6**, Plates 1-104.
- (1964) Oedogoniacées Africains. *Nova Hedw.* **7**, 151-158.
- HARDY, A. D. (1906) Freshwater algae of Victoria. III. *Vict. Nat.*, **23**, 18-22, 33-42.
- KOLKWITZ, R. & KRIEGER, H. (1941) Zygnemales. Vol. 13, Part. 2. In L. Rabenhorst *Kryptogamen-Flora von Deutschland und der Schweiz*. (Becker & Erler Kom.-Ges: Leipzig.)
- MAY, V. (1973) The algal genus *Scenedesmus* in Australia. *Contrib. N.S.W. Natl. Herb.*, **4**, 431-452.
- PRESCOTT, G. W. (1951) *Algae of the Western Great Lakes Area*. Cranbrook Institute of Science, Bulletin No. 31 Michigan.
- & SCOTT, A. M. (1952) Some South Australian desmids. *Trans. R. Soc. S. Aust.* **75**, 55-69.
- TIFFANY, L. H. (1924) Some new forms of *Spirogyra* and *Oedogonium*. *Ohio J. Sci.*, **24**, 180-190.
- TIFFANY, L. H. (1930) *The Oedogoniaceae* (Columbus: Ohio).
- TUPA, D. (1974) An investigation of certain Chaetophoracean algae. *Beith Nova Hedw.* **46**, 1-155.

A NEW SPECIES OF NEPHRURUS (REPTILIA: GEKKONIDAE) FROM SOUTH AUSTRALIA

BY CHRIS HARVEY

Summary

A new species of Knob-tailed Gecko from the mid-north of South Australia is described here as *Nephrurus deleani* sp. nov. It is most like *N. stellatus* Storr, *N. laevissimus* Mertens and *N. vertebralis* Storr, from which it differs mainly in caudal scalation and dorsal patterning. Notes on habitat and aspects of biology are included.

A NEW SPECIES OF *NEPHRURUS* (REPTILIA: GEKKONIDAE) FROM SOUTH AUSTRALIA

by CHRIS HARVEY*

Summary

HARVEY, C. (1983) A new species of *Nephurus* (Reptilia: Gekkonidae) from South Australia. *Trans. R. Soc. S. Aust.* **107**(4), 231-235, 30 November, 1983.

A new species of Knob-tailed Gecko from the mid-north of South Australia is described here as *Nephurus deleani* sp. nov. It is most like *N. stellatus* Storr, *N. laevis* Mertens and *N. vertebralis* Storr, from which it differs mainly in caudal scalation and dorsal patterning. Notes on habitat and aspects of biology are included.

KEY WORDS: *Nephurus*, taxonomy, Pernatty Lagoon, allopatric, Gekkonidae, Reptilia, new species.

Introduction

The gekkonid genus *Nephurus* is widely distributed throughout arid Australia and three species have been recorded from South Australia. *Nephurus levis* De Vis, the most wide spread member of the genus, is found throughout the State north of Port Augusta. Two records also exist from the Dangali Conservation Park, approximately 80 km north of Renmark.

Nephurus stellatus Storr extends westwards from Eyre Peninsula to southern Western Australia.

Nephurus laevis Mertens occurs in the western half of South Australia, north of the Trans Australia Railway and west of the Stuart Highway (Fig. 1).

In 1971 a juvenile specimen of *Nephurus* from Pernatty Lagoon was identified as *Nephurus vertebralis* Storr probably due to the presence of a pale vertebral stripe which extended from just behind the head to the end of the tail.

Additional specimens from Pernatty Lagoon represent a new species which is described here.

Materials and Methods

All material examined in this paper is deposited in the following institutions: South Australian Museum Adelaide (SAM), Western Australian Museum Perth (WAM) and the Museums and Art Galleries of the Northern Territory Darwin (NTM).

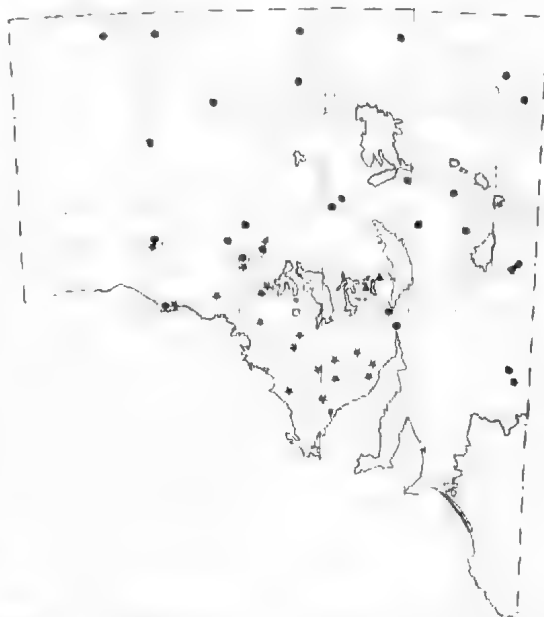


Fig. 1. Distribution of the Genus *Nephurus* in South Australia based on the records of the South Australian Museum, triangles = *N. deleani*, closed circles = *N. levis*, open circles = *N. laevis*, stars = *N. stellatus*.

Specimens were measured with dial callipers to the nearest 0.1 mm, following Storr (1968). Measurements taken were: snout-vent length (SVL), tail length (TL), head length (HL), head width (HW), horizontal diameter of eye (ED), length of ear aperture (EA), inter-orbital distance (IOD), internostril distance (ID), hindlimb length (HLL). Scale counts recorded were: longitudinal rows of tubercles (LRT), caudal annuli (CA), interorbitals (IO). Comparisons between some of these characters are recorded on Table 1. Standard deviations are included for each mean.

* 20 Crozier Terrace, Oaklands Park, S. Aust. 5046.

***Nephrurus deleani* sp. nov.**

FIGS 1, 2, 3.

Holotype: SAM R21868, adult female collected on 24.iv.1981 by S. Delean 44 km south-east of Pimba, S.A. (31°31'S, 137°08'E).

Diagnosis: A relatively large terrestrial gecko with short, narrow, slightly depressed tail, terminating in small knob. Dorsal colour pattern highly variable, pale vertebral stripe present in some juveniles.

Description of holotype:

Scalation: Head scales small, juxtaposed; largest in occiput and interorbital region; smallest in gular and postocular areas. Neck with scattered, conical tubercles, smaller than those on occiput. Upper labials 15, lower labials 20; larger than surrounding scales. Dorsal surface covered with small, granular scales, uniformly intermingled with tubercles; tubercles largest on sacrum, smaller than those on occipital and interorbital regions and surrounded by scales of same size and shape as those on rest of dorsal surface. Forelimbs covered with small granular scales, interspersed with a few small tubercles. Hindlimbs covered with small, granular scales, interspersed with large, conical tubercles most prominent on thighs and slightly smaller than tubercles on dorsal surface. Scales on ventral surface uniformly small, flat and juxtaposed. Upper surface of tail covered with small scales; 9 regular longitudinal rows of conical, mucronate tubercles, smaller in diameter than those on dorsum, pointing backwards and surrounded by a ring of scales slightly larger

than those on rest of upper caudal surface. Caudal annuli 17.

Colouration: Dorsal ground colour light brown, intermingled with dark brown-black areas, with alternate fawn and dark brown transverse bars (Fig. 2). Flanks spotted, sacrum predominantly dark brown. Tubercles are brown except those occurring on spots and transverse bars, which are fawn. Ventral surface white. Head light brown, intermingled with areas of fawn and dark brown. Labials light brown. Distinct short, thick fawn coloured bar, which bends back slightly to form "V" on occiput. Second bar runs across neck; third pale bar originating at neck, distinctly "V" shaped and extending back diagonally to mid-dorsal line. Dorsal surface of tail predominantly dark brown. Tubercles white, except for a few dark brown ones on proximal annuli. Under-surface of tail off-white.

Holotype measurements (in mm): SVL 79.3; TL 27.2; HL 24.5; HW 19.4; HLL 35.4; ED 5.6; EA 2.4; IOD 3.3; ID 3.5.

Etymology: This species is named for Mr Steven Delean, who collected the holotype and most of the paratypes.

Distribution

Specimens of *Nephrurus deleani* have been collected only from the *Acacia* vegetated sand hills immediately north and west of Pernatty Lagoon, despite extensive searching to the north and to the south as far as Uro Bluff (32°08'S, 137°36'E). *N. deleani* is allopatric with the closely related *N. stellatus*.

Variation

There are 4 paratypes, all are from 44 km south of Pimba, S.A. (31°31'S, 137°08'E): WAM R80751, an adult female, 23.iv.1982, C. Harvey and S. Delean; SAM R21865-66, juvenile females, 24.iv.1981, S. Delean; SAM R21867, juvenile male, 25.iv.1982, M. Francis. Unlike other congeners, specimens of *N. deleani* show considerable variation in dorsal colour patterning, not only between adults, but also between adult and juvenile specimens. Even the most consistent features of dorsal patterning—the fawn transverse bars and the spotted flanks—are absent or highly modified in some *N. deleani*.

Juveniles differ from adults in having a much darker background colour, with more distinct body markings. Of 32 juvenile *N.*

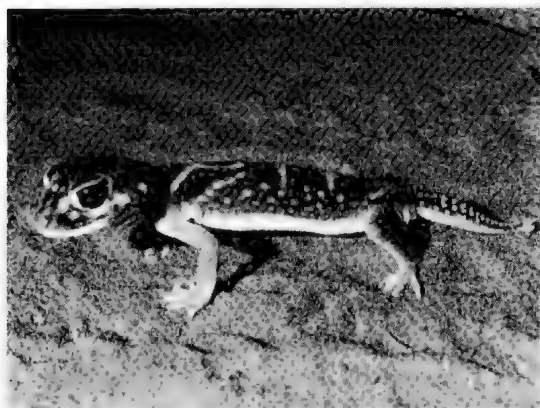


Fig. 2. *Nephrurus deleani* sp. nov. in life.

TABLE 1. Comparison of 6 characteristics between the five species examined.
Character

	TL/SVL	HL/SVL	IO	DT	LRT	CA
<i>N. deleani</i>	35.8 \pm 3.3 (27.6–40.2) n = 14	30.0 \pm 2.4 (24.5–33.6) n = 14	5.2 \pm 0.7 (4–6) n = 6	single	9.2 \pm 0.4 (9–10) n = 6	15.7 \pm 0.8 (15–17) n = 6
<i>N. stellatus</i>	30.1 \pm 3.3 (23.1–46.0) n = 22	30.9 \pm 4.9 (23.1–35.2) n = 22	5.1 \pm 0.7 (4–7) n = 46	rosette-shaped	5.7 \pm 0.5 (5–7) n = 31	11.2 \pm 1.2 (9–14) n = 32
<i>N. vertebralis</i>	35.0 \pm 2.0 (32.5–37.8) n = 5	29.5 \pm 1.2 (28.3–31.2) n = 5	5.1 \pm 0.3 (5–6) n = 9	single	7.8 \pm 0.4 (7–8) n = 8	18.3 \pm 0.8 (17–19) n = 8
<i>N. laevis</i>	33.4 \pm 3.4 (28.8–37.4) n = 12	33.0 \pm 3.5 (29.9–43.3) n = 14	6.1 \pm 0.6 (5–7) n = 21	absent	6.7 \pm 0.4 (5–7) n = 18	18.3 \pm 1.8 (13–19) n = 14
<i>N. levis</i>	44.9 \pm 4.9 (31.0–60.2) n = 62	32.9 \pm 4.3 (28.0–40.8) n = 94	4.7 \pm 0.7 (4–8) n = 94	single	8.3 \pm 0.8 (6–10) n = 62	17.2 \pm 1.5 (12–21) n = 62

deleani collected, only 3 have shown an obvious vertebral stripe; in none of these is the stripe as wide, or as obvious as it is in *N. vertebralis*.

Comparisons with other congeners

The dorsal colour pattern of *N. deleani* distinguishes it from all congeners.

N. deleani differs from *N. levis* by having a much shorter, narrower, less depressed tail (Table 1). The fore and hind limbs of *N. levis* are more heavily tuberculated than in *N. deleani*.

N. deleani is distinguished from *N. vertebralis* in having more longitudinal rows of caudal scales (Table 1), a shorter ear slit, fewer tubercles on the fore and hind limbs and complete absence of a vertebral stripe in adult specimens.

The absence of tubercles on the dorsal surface, a lower number of longitudinal rows of tubercles on the tail and differences in dorsal patterning distinguish *N. laevis* from *N. deleani* (Table 1).

N. deleani has more caudal annuli and more longitudinal rows of caudal tubercles (Table 1) than *N. stellatus*. It further differs from *N. stellatus* by having dorsal tubercles surrounded by a ring of scales similar in size to those occurring between the tubercles, rather than larger (Fig. 3).

Habitat

The area occupied by *N. deleani* is isolated geographically from other *Nephrurus* populations. The high number of salt lakes that encircle the area, together with the presence

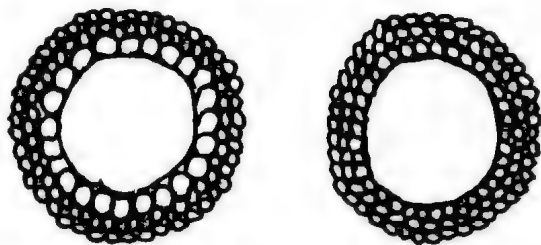


Fig. 3. Dorsal tubercle pattern of left, *N. stellatus* and right, *N. deleani*.

of the Gawler Ranges to the south-west would effectively prevent interbreeding between *N. deleani* and *N. laevis* and *N. stellatus*. *N. deleani* has been collected only on the crests of sand dunes that are devoid of *Triodia* and are dominated by *Acacia aneura* and *A. ligulata*. *N. deleani* habitat is more similar to that preferred by *N. vertebralis* (Pianka & Pianka, 1976) than to that of *N. stellatus*, which occurs exclusively in *Triodia-Eucalyptus* associations.

Notes on biology

In common with other congeners, *N. deleani* will readily feed upon a variety of insects and arachnids in captivity, with adult specimens primarily consuming small geckos. *Rhynchoedura ornata* Günther and *Diplodactylus damaeus* (Wermuth), which are sympatric with *N. deleani*, probably form a large part of the diet of adult specimens.

Only limited data are available on reproductive habits. One female (SVL 95 mm, weight 11.7 g) deposited 2 eggs, measuring

22 × 12 mm and 22 × 13 mm, on 3.iii.1981. Another female (SVL 92 mm, weight 16.5 g) collected by the author on 24.iv.1982, contained two eggs which had still not been laid by 18.vii.1982.

Material examined:

South Australia:—

Nephrurus levis: SAM R152 (Oodnadatta); SAM R707, R878 (Wynbrigg RS); SAM R1884A-B (Tarcoolia); SAM R1962A-B (Smithfield—locality doubtful); SAM R1963 (Murnpeowie); SAM R1968 (between Everard and Barrow Ranges); SAM R1985 (between Ooldean and Fowler's Bay); SAM R3109A-B (Ernabella); SAM R3709 (Mudoorina Station); SAM R4298 (16 km south of Cadelga HS); SAM R4992A-C (Lake Coungie); SAM R5443 (Dalhousie Springs); SAM R5503 (Callabonna Station); SAM R7556–R7566 (Muggrave Park); SAM R7586 (Itari Rocks); SAM R1888, R9010 (Port Augusta); SAM R14171 (Hesso); SAM R14631 (20 km east of Ammaroodinna Hill, Granite Downs Station); SAM R14880 (Glenmaynie Bore); SAM R14555A-B (22 km west-north-west of Morolana HS); SAM R15498, R16728 (10 km north-west of Emu); SAM R17278/9 (Wastell's Dam, Billa Kalina Station); SAM R17296 (Patterson's Dam, Billa Kalina Station); SAM R17807 (Wooltana Station); SAM R18069 (Simpson Desert Conservation Park); SAM R18203 (approximately 15 km south-west of Wyola Lake); SAM R18204 (approximately 85 km north of Wyola Lake); SAM R18238 (approximately 20 km north of Wyola Lake); SAM R19202 (Kallakooopah Creek); SAM R19213 (8 km north of Kallakooopah Creek); NTM R1020 (100 km north of Renmark).

Nephrurus laevis: SAM R661, R665, R1653A (Ooldean); SAM R3298 (30 km south of Emu); SAM R14053 (Tarcoolia); SAM R14632 (20 km east of Ammaroodinna Hill, Granite Downs Station); SAM R14987A-D (7 km west of Immarna RS); SAM R15497B (10 km north-west of Emu); SAM R15566A-B (103 km west of Vokes Hill Corner); SAM R15609 (12 km north-west of Wardarie, Parkalidga Rockhole); SAM R15792 (9 km east of Maralinga); SAM R16761 (Wilgena Station); SAM R17462 (North-West Conservation Park); SAM R17490 (45.7 km south of Vokes Hill); SAM R18221–2 (approximately 85 km north of Wyola Lake); SAM R18241 (approximately 20 km south-west of Wyola Lake).

Nephrurus stellatus: SAM R641 (Kielpa, West Coast); SAM R1964 (Baringa—locality doubtful); SAM R3209A-D (Ooldean Soak); SAM R5284 (Ceduna); SAM R11461 (Port Neel); SAM R12415A-C (Bascombe's Well National Park); SAM R13438 (Hinck's National Park); SAM R13746 (Childara Rockhole); SAM R14054A–H (Tarcoolia); SAM R14056A (Ooldean); SAM R14561A–B (approximately 30 km north-east of

Cowell); SAM R15205A-B (28 km north-east of Wirrulla); SAM R15006A-C (23 km north of Kaonibba Mission); SAM R15384 (30 km west of Childara Rockhole); SAM R15734A-B, R15793 (65 km west of Meelera Rockhole); SAM R17663 ('Melaleuca', 30 km west of Kintia); SAM R17954 (Lake Gilles Conservation Park); SAM R18515–6 (Pancay Station, Gawler Ranges); SAM R19597/9 (60 km south-west of Whyalva).

Western Australia:—

Nephrurus verticillatus: WAM R5300 (Wadgin-garru); WAM R13112 (Yuin Station); WAM R48712 (Plumridge Lakes area); WAM R49242 (approximately 40 km east of Paynes Find); WAM R53023 (40 km south of Yindolbarra); WAM R53548 (27 km east of Pt. Sunday, Great Victoria Desert); WAM R53574 (8 km east of Pt. Sunday); WAM R70120 (presumably 7.5 km north of Dandaraga HS); WAM R78156 (10 km south of Leonora).

Northern Territory:—

Nephrurus levis: NTM R693 (Tanami Sanctuary); NTM R761 (6.5 km north of Alice Springs); NTM R1403 (107.8 km west of Yuendumu); NTM R1409 (31 km west of Mt Doreen); NTM R1410 (33.6 km west of Mt Doreen); NTM R1446 (228.8 km west of Yuendumu); NTM R1488–1500, R1511, R1747 (between 10.8 and 33 km west of Rabbit Flat Roadhouse); NTM R1535, R1566, R1580 (Horden Hill, Granites); NTM R1595–97, R1639, R1848 (Maryvale); NTM R1695 (Northern Territory); NTM R1607, R1844–1847 (between 4 km and 20 km east of Maryvale); NTM R2052 (west of Yuendumu); NTM R2466, R3764 (Alice Springs); NTM R8620 (30 km east of Three Ways); NTM R9846 (90 km east of Three Ways).

Acknowledgments

I am grateful to Dr G. M. Storr (Western Australian Museum), Mr G. F. Gow (Museums and Art Galleries of the Northern Territory) and Dr T. D. Schwaner (South Australian Museum) for the loan of *Nephrurus* specimens in their care.

I thank Terry Schwaner and Brian Miller who gave constructive comments and criticisms of the manuscript and Mark Francis, Brett Leane and Andrew Mower for their assistance in the field. I am particularly grateful to Steven Delean for his assistance in both the field and laboratory and for permission to use his unpublished data in Table 1.

I thank Winnie Feijen for typing the manuscript and Jan Haughton, Sue Hamilton, Kerry Regan and Keith Richards for their encouragement and assistance throughout the project.

References

- COGGER, H. G. (1979) Reptiles and Amphibians of Australia. (A. H. & A. W. Reed: Sydney).
- KINGHORN, J. R. (1924) Reptiles and batrachians from south and south-west Australia. *Rec. Aust. Mus.* **14**(3), 166-167.
- PIANKA, E. R. & PIANKA, H. D. (1976) Comparative Ecology of Twelve Species of Nocturnal Lizards in the Western Australian Desert. *Copeia*, 1976 (1), 125-142.
- STORR, G. M. (1963) The gekkonid genus *Nephurus* in Western Australia, including a new species and three new subspecies. *J. Roy. Soc. West. Aust.* **46**(3) 85-90.
- (1968) *Nephurus stellatus*, a new species of knob-tailed gecko from southern Australia. *West. Aust. Nat.* **10**(1), 180-182.
- WAITE, E. R. (1929) The Reptiles and Amphibians of South Australia. (Government Printer: Adelaide).

THE FROG FAUNA OF THE BARKLY TABLELAND, NORTHERN TERRITORY

BY MICHAEL J. TYLER, MARGARET DAVIES & ANGUS A. MARTIN

Summary

Ten species of frogs are reported from the Barkly Tableland and an additional species is considered likely to occur there. All museum voucher specimens and localities are cited.

THE FROG FAUNA OF THE BARKLY TABLELAND, NORTHERN TERRITORY

by MICHAEL J. TYLER*, MARGARET DAVIES* & ANGUS A. MARTIN†

Summary

TYLER, M. J., DAVIES, M. & MARTIN, A. A. (1983) The frog fauna of the Barkly Tableland, Northern Territory. *Trans. R. Soc. S. Aust.* 107(4), 237-242, 30 November, 1983.

Ten species of frogs are reported from the Barkly Tableland and an additional species is considered likely to occur there. All museum voucher specimens and localities are cited.

KEY WORDS: Barkly Tableland, frogs, distribution.

Introduction

The Barkly Tableland of the Northern Territory is poorly defined as a physiographic entity. For the purposes of groundwater studies Randal (1967) adopted arbitrary limits bounding an area of approximately 102 000 km² of various soils including blacksoil plains. These plains are bisected by major creeks which drain predominantly towards the south via the Georgina River, and constitute the northern boundary of the Eyrean drainage system. The original vegetation has been modified by grazing, and the plains now principally support low grasses, whereas the watercourses are flanked by eucalypts. The region is characterised by very high summer temperatures and a low annual rainfall which often falls in a few days. Heavy summer rains result from depressions following cyclonic activity to the north of the area.

Knowledge of the vertebrate fauna of the area depends heavily upon W. H. Stalker who was employed on Alexandria Station as a collector by Sir William Ingram and J. Forrest in 1905. His collections were deposited in the British Museum (Natural History); the mammals were reported by Thomas (1906), and the birds by Ingram (1907).

Stalker also assembled a small collection of frogs, but it was not reported as a single unit, and subsequently it was dispersed to various institutions. However details have appeared in the literature in a number of publications. Loveridge (1935) reported *Cyclorana australis* ("*Chiroleptes australis*") and *Litoria alboguttata* ("*Mitrolysis alboguttata*"). Parker (1940) described *C. cultripes* and *Uperoleia orientalis* ("*Glauertia orientalis*"), and reported *C. australis*, but questioned the identity of *L.*

alboguttata. Tyler (1974) reidentified the disputed specimen as a topotypic *C. cultripes*.

B. L. Troughton and J. J. Fletcher of the Australian Museum visited Alexandria Station in 1934 and obtained further frogs, but their collection also was not reported as a unit. From their material Copland (1957) reported *Litoria rothii* ("*Hyla peronii*") and *L. rubella* ("*Hyla rubella*").

Moore (1961) reported *L. caerulea* ("*Hyla caerulea*") from amongst specimens collected by Stalker, whilst Tyler and Martin (1977) reported *C. cultripes* collected in 1970 by B. Low and D. F. Gartside at Alroy Downs, west of Alexandria Station.

Tyler, Davies and Martin (1981) suppressed *Glauertia* Loveridge and referred *G. orientalis* to *Uperoleia* Gray. They concluded that other records of the species from the Northern Territory were based on undescribed species, and that *orientalis* should be restricted to the Alexandria Downs holotype and paratype and the single paratype taken at Groote Eylandt in the Gulf of Carpentaria.

In summary, the currently reported frog fauna of the Barkly Tableland comprises *C. australis*, *C. cultripes*, *Litoria caerulea*, *L. rothii*, *L. rubella* and *Uperoleia orientalis*.

In December 1981 we visited the Barkly Tableland to collect frogs and, particularly, to attempt to obtain topotypic *U. orientalis*. Here we report the species collected, and we also assembled other data to permit an assessment of the nature and diversity of the frog fauna.

Materials and Methods

The specimens reported here are deposited in various institutions abbreviated as follows: AM (Australian Museum), AMNH (American Museum of Natural History), UAZ (Department of Zoology, University of Adelaide), BMNH (British Museum, Natural History), CAWC (Central Australian Wildlife Collection, Conservation Commission of the

* Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, S. Aust. 5001.

† Department of Zoology, University of Melbourne, Parkville, Vic. 3052.

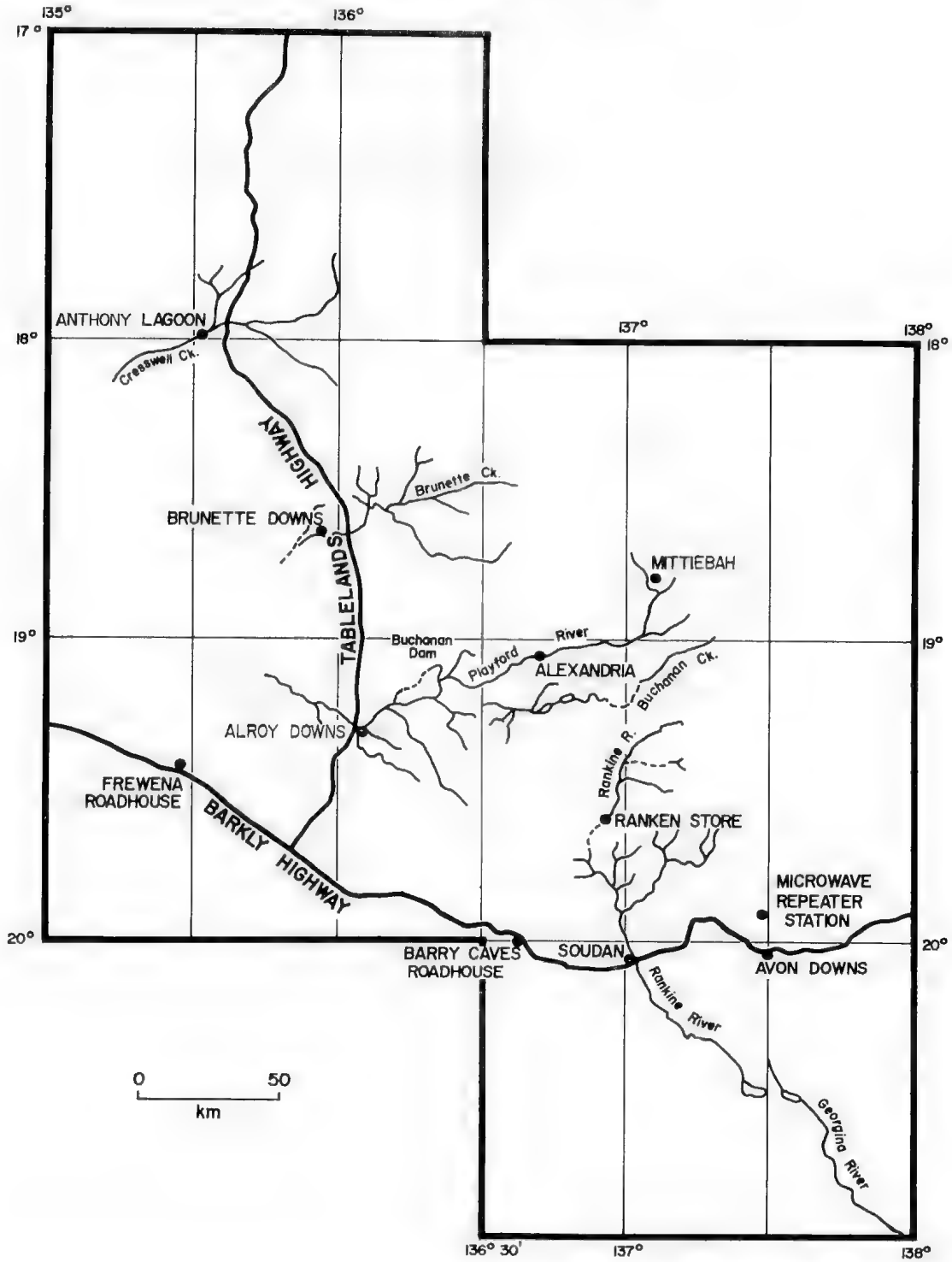


Fig. 1. Barkly Tableland, Northern Territory, showing localities mentioned in the text.

N.T., Alice Springs), KU (Museum of Natural History, University of Kansas), MCZ (Museum of Comparative Zoology, Harvard University), NTM (Northern Territory Museum), SAM (South Australian Museum). Letters preceding registration numbers identify institutional catalogues.

Our collection was assembled during the period 14.xii.81 and our collecting sites and other localities cited here are shown in Figure 1. On occasions we heard the male calls of other species but failed to locate voucher specimens; in each of these cases, we were in agreement about the identity of the calling individuals.

Literature records reporting species from "Alexandria Station" are too imprecise to permit the assumption that they occur on the Barkly Tableland. When Stalker obtained his collection Alexandria Station extended from what is now the Barkly Highway in the south for 500 km to the Gulf of Carpentaria, far beyond the northern boundary of the Barkly Tableland (Figure 1). Therefore we have sought to confirm the existence of such species within the boundary. In instances where voucher specimens or voice records are not available, we have extrapolated from our data on habitat requirements elsewhere in the Northern Territory, in particular on the black-soil plains at Newcastle Waters.

pH measurements were obtained with a Jenco Model 609 portable pH meter. Water temperatures were recorded with a Digitron Model 4706 digital thermometer or Schutheiss 0–50°C rapid-reading thermometer.

Species account

Family: HYLIDAE

Cyclorana australis (Gray)

Locality Records: Alexandria Station—Loveridge (1935), Parker (1940), Tyler & Martin (1975); 22 km N of Alexandria Station—AM R11351, 11358; Anthony Lagoon—NTM 3632; Brunette Downs—NTM R3663, 3675–76; Tableland Highway, 4 km S of Anthony Lagoon/Brunette Downs boundary—NTM 5797–99.

Comments: We did not locate any specimens but the locality records suggest a widespread distribution on the Barkly Tableland.

Cyclorana cultripes Parker

Locality Records: Alexandria Station—Parker (1940), Tyler (1967); Alroy Downs—Tyler & Martin (1977); Avon Downs Police Station—NTM R9731–49; 5 km SW of Alroy Downs Station—NTM R9889–90, SAM R22490–98;

Frewena—NTM R5448–62, 8434–36, 9625–26, 9645–71.

Comments: On 15 December we collected 11 recently metamorphosed frogs amongst damp leaf litter within 0.5 m of the edge of a newly constructed dam approximately 5 km SW of Alroy Downs Station. The specimens range in snout to vent length 15.4–18.2 mm, and the existence of the frogs was indicated by activity in the water where we found 10 dytiscid beetles: *Eretes australis* (Erichson) eating a specimen. A daytime water temperature of 35.2°C was recorded at the site; the pH was 6.98.

Analysis of the stomach contents of nine of the juvenile frogs showed a large proportion of Collembola in the diet together with small beetles, flies, spiders and mites.

We heard a single specimen calling on 14.xii.81 from a temporary pool approximately 500 m north of the Barkly Highway, at a site 1.5 km south of Microwave Repeater Station 8502 and 5 km east of Soudan Outstation, Alexandria Station.

Cyclorana platycephalus (Günther)

Locality Records: No. 26 Bore, Alroy Downs—NTM 9711–16; Dunmarra Roadhouse—NTM 8609; 8 km S of Dunmarra—NTM 9598–9604, 9674.

Comments: The series consists of 14 adult specimens. This species has not been reported from the Northern Territory since its first collection by the Horn Expedition at Charlotte Waters in 1895 (Spencer 1896). However it was taken at the same locality by M. Gillam and C. Horner on 22.iii.71 (SAM 16921; 4 specimens). The new localities represent a northern range extension of the species of up to 1500 km.

Tyler (1978, Fig. 14) plotted the geographic boundaries of the specimens then available in all Australian museums, and demonstrated that the range of the species is less extensive than supposed by Barker & Grigg (1977) and Cogger (1979) and that it apparently comprises two allopatric populations. One is centred upon the Pilbara of Western Australia, and the other occupies a roughly triangular block, ranging across southwestern Queensland, northwestern New South Wales and northeastern South Australia, and just enters the Northern Territory at Charlotte Waters.

The location of specimens at Alroy Downs and Dunmarra so far north of the existing

eastern population, suggests that the Barkly Tableland population is a third isolate.

Litoria caerulea (White)

Locality Records: Alexandria Station—Moore (1961); Anthony Lagoon—NTM R3632; Brunette Downs—NTM R3663, 3675–76; Tableland Highway, 4 km S of Anthony Lagoon/Brunette Downs boundary—NTM 5797–99.

Comments: We did not locate specimens, but we heard one calling from the conservatory at Alroy Downs Homestead on 16.xii.81.

Litoria rothli (de Vis)

Locality Records: Alexandria Station—Copland (1957).

Comments: Copland (1957) reported a specimen (as *H. peronii*) collected by Troughton & Fletcher in 1930. This represents the southernmost record of the species in the N.T. On the Rankine River at Ranken Store we heard a single call from a distance of several hundred metres that we attributed to *L. rothli*, but it was not repeated, and we were unable to confirm the presence of the species in the area. It could be expected to occur on the northern portion of the Barkly Tableland.

Litoria rubella (Gray)

Locality Records: Alexandria Station—AM R11355–57; Copland (1957); 22 km N of Alexandria Station—AM R11351, 11353; Brunette Downs—NTM R3664.

Comments: We heard this species on 14.xii.81 calling from vegetation beside a temporary pool approximately 500 m north of the Barkly Highway, 1.5 km south of microwave Repeater Station 8502, which is 5 km east of Soudan Outstation, Alexandria Station. We also heard the species calling from trees in the flooded Rankine (= Rankin = Ranken) Creek adjacent to the abandoned Ranken Store, approximately 120 km north of the Barkly Highway (Fig. 1).

Family: LEPTODACTYLIDAE

Neobatrachus aquilonius Tyler, Davies & Martin

Locality Records: Frewena Roadhouse, Barkly Highway—NTM 9628–44.

Comments: This recently described species has not been reported from the N.T., but the geographic gap between the present site and the records from the Kimberley, W.A. is bridged by specimens taken at Tennant Creek by J. Field (SAM R5086–87) and in the Tanami Desert by M. Gillum and I. Andrews (SAM

R23474). The Frewena series was collected by G. Gow and P. Horner on 6.ii.1981 in a small puddle on the floor of a drained swimming pool. Every specimen exhibits damage to hands and feet consistent with the frogs trying to burrow into the hard surface.

Damage to the fourth toe prevents the use of foot length as a diagnostic character distinguishing the species from *N. centralis* (Parker) (Tyler *et al.* 1981). However the other external morphological features are consistent with *N. aquilonius* (Table 1).

TABLE 1. Morphometric comparisons of *Neobatrachus aquilonius* from Western Australia and Northern Territory.

	Frewena N.T.	W.A. (types)
n	17	18
S-V (♂♂)	46.3–49.8 mm	47.9–53.9 mm
S-V (♀♀)	46.4–55.6 mm	52.2–59.0 mm
TL/S-V	0.30–0.37	0.29–0.35
E-N/IN	1.08–1.31	0.93–1.31

Notaden nichollsi Parker

Locality Record: Barkly Highway between Frewena Roadhouse and Three-Ways—NTM R5348–60.

Comments: The inclusion of this species in the Barkly Tableland fauna is based on the assumption that it occurs further east than this record, which may be beyond the customarily recognised western boundary of the area.

Ranidella deserticola Liem & Ingram

Locality Records: Anthony Lagoon—Tyler *et al.* (1981a); Avon Downs—NTM R9730.

Comments: The existence of this species at the Elliot-Newcastle Waters area (Tyler *et al.* 1981a), at Avon Downs near the Queensland border, and at the intermediate locality of Anthony Lagoon indicates that it is probably associated with permanent water throughout the Barkly Tableland.

Uperoleia orientalis (Parker)

Locality Record: Alexandria Station—Parker (1940), Tyler *et al.* (1981b).

Comments: The type locality is "Alexandria Station" which at the date of collection (1905) extended as far north as the Gulf of Carpentaria. Two paratypes are topotypic; the third is from Groote Eylandt in the Gulf of Carpentaria. We have examined the series and consider that all are conspecific. We believe that it is unlikely that the same *Uperoleia*

species would occur on such diverse sites as Groote Eylandt and the blacksoil plains, and therefore we conclude that the type locality is situated in the Gulf country perhaps adjacent to Groote Eylandt. It is unlikely that the species occurs on the Barkly Tableland.

Uperoleia trachyderma Tyler, Davies & Martin

Locality Records: AMNH 114049-50, KU 192133-4, NTM R9887-8, SAM R22336-48, UAZ A622, Rankine River at Ranken Store, Alexandria Station, N.T., 16.xii.81; SAM R22325-35, UAZ A621, Barkly Highway, 500 m N of Microwave Repeater 8502, Soudan Outstation, Alexandria Station, N.T., 16.xii.81; CAWC R3676, Brunette Downs, 23.v.77; CAWC A18 (2 specimens) 24 km S of Wallhallow Homestead.

Comments: We described this species (Tyler *et al.* 1981a) from material collected at Newcastle Waters on a floodplain approximately 130 km southwest of the northern boundary of the Barkly Tableland. We encountered the species at the first two locations described above. These localities extend the known geographic range of the species approximately 500 km southeastwards; its presence in the Rankine River indicates that it probably also extends into western Queensland. We have located additional representatives (listed) that had been misidentified previously.

Our series consists of 36 adult males ranging in snout to vent length 19.3-23.8 mm.

Limnodynastes spenceri Parker

Comments: Although this species has not been reported from the Barkly Tableland and was not heard or seen by us, its extremely wide distribution in the arid zone of W.A., N.T. and Queensland supports our assumption that it occurs there.

Barkly Tableland frog fauna

Despite the limited variety of habitats within the Barkly Tableland there is a sur-

prisingly rich frog fauna. Opportunities to locate specimens are rare and generally follow heavy rain.

As a result of our review the frog fauna known to occur in the area has been increased from six to 10 or 11 species. *Uperoleia orientalis* is considered to occur outside the geographic area, and is deleted from the former list. Species marked below with an asterisk have not been reported previously.

Hylidae

Cyclorhina australis
C. cultripes
*C. platycephalus**
Litoria caerulea
L. rothli
L. rubella

Leptodactylidae

*Neobatrachus aquilanius**
*Notaden nichollsi**
*Ranidella deserticola**
*Uperoleia trachyderma**
*?Limnodynastes spenceri**

Acknowledgments

This investigation was supported in part by an ARGS grant to M.J.T., and the field studies were undertaken with the permission of the N.T. Wildlife Commission. We are deeply indebted to Bruce McRae (Tennant Creek Council) for invaluable assistance in the preparation of our field studies. John Ohlsen (Alexandria Station) and Jim Perryman (Alroy Downs Station) provided other assistance.

We thank the Australian National University for access to a four-wheel drive vehicle, and Ansett Airlines for generous aid to our transportation needs. Keith Walker (Department of Zoology, University of Adelaide) identified the dytiscids, and Shane Parker (South Australian Museum) provided valuable advice on data sources.

References

- COPLAND, S. J. (1957) Australian tree-frogs of the genus *Hyla*. *Proc. Linn. Soc. N.S.W.*, **82**, 9-108.
- INGRAM, C. (1907) On the birds of the Alexandra District, North Territory of South Australia. *Ibis*, Series 9, **1**, 387-415.
- LOVERIDGE, A. (1933) A new genus and three new species of crinine frogs from Australia. *Ocean. Pap. Boston Soc. Nat. Hist.*, **8**, 89-94.
- MOORE, J. A. (1961) The frogs of eastern New South Wales. *Bull. Am. Mus. Nat. Hist.*, **121**, 149-386.
- PARKER, H. W. (1940) The Australasian frogs of the family Leptodactylidae. *Novit. Zool.*, **42**, 1-106.
- RANDAL, M. A. (1967) Groundwater in the Barkly Tableland, N.T. *Bull. Bur. Miner. Resour. Geol. Geophys.*, **91**, 111 pp.
- THOMAS, O. (1906) On Mammals from Northern Australia presented to the National Museum by Sir Wm. Ingram, Bt., and the Hon. John Forrest. *Proc. Zool. Soc. London*, **37**, 536-543.
- TYLER, M. J. (1974) The systematic position and geographic distribution of the Australian frog *Chiropletes alboguttatus* Gunther. *Proc. R. Soc. Qld*, **85**, 27-32.
- , DAVIES, M. & MARTIN, A. A. (1981b) Australian frogs of the leptodactylid genus *Uperoleia* Gray. *Aust. J. Zool.*, Suppl. Ser. (79), 1-64.

- , —— & —— (1981b) Frog fauna of the Northern Territory: new distributional records and the description of a new species. *Trans. R. Soc. S. Aust.* **105**, 149-154.
- , & MARTIN, A. A. (1975) Australian leptodactylid frogs of the *Cyclorana australis* complex. *Ibid.* **99**, 93-99.
- , & —— (1976) Taxonomic studies of some Australian leptodactylid frogs of the genus *Cyclorana* Steindachner. *Rec. S. Aust. Mus.* **17**(15), 261-276.

ADDITIONS TO THE FROG FAUNA OF THE NORTHERN TERRITORY

BY MICHAEL J. TYLER. GRAEME F. WATSON & MARGARET DAVIES

Summary

Cyclorana vagitus, *Limnodynastes tasmaniensis* and *Uperoleia borealis* are reported from the N.T. for the first time. All occur in the north of the territory. The structure of the mating call of *C. vagitus* is described and figured.

ADDITIONS TO THE FROG FAUNA OF THE NORTHERN TERRITORY

by MICHAEL J. TYLER*, GRAEME F. WATSON† & MARGARET DAVIES‡

Summary

TYLER, M. J., WATSON, G. F. & DAVIES, M. (1983) Additions to the frog fauna of the Northern Territory *Trans. R. Soc. S. Aust.* 107(4), 243-245, 30th November, 1983.

Cyclorana vagitus, *Limnodynastes tasmaniensis* and *Uperoleia borealis* are reported from the N.T. for the first time. All occur in the northwest of the territory. The structure of the mating call of *C. vagitus* is described and figured.

KEY WORDS: new records, frogs, Northern Territory, call, audiospectrogram, distribution.

Introduction

Within the last decade the known frog fauna of the Northern Territory has increased substantially. Tyler (1976) listed only 25 species whereas six years later the total had risen to 36 (Tyler 1982). Whilst the latter work was in press *Ranidella deserticola* Liem & Ingram was reported from the N.T., and a further species (*Uperoleia trachyderma* Tyler, Davies & Martin) was described from near Newcastle Waters (Tyler *et al.* 1981a). In addition, Tyler, Davies & Martin (1983) reported the presence, on the Barkly Tableland, N.T., of *Neobatrachus aquilonius* Tyler, Davies & Martin, formerly known only from W.A.

In February 1982 we travelled by road from Darwin to Halls Creek, W.A., via Katherine and Kununurra, and returned by the same route. Three of the species collected on the Victoria Highway between Katherine and Kununurra represented additions to the fauna of the N.T. Here we report these collections and provide additional biological data on them.

Material and Methods

The specimens reported here are lodged in the collections of the South Australian Museum (SAM) and Department of Zoology, University of Adelaide (UAZ).

Methods of measurement follow Tyler (1968). Osteological data were obtained from cleared and Alizarin Red and Alcian blue stained preparations using the technique of Dingerkus and Uhler (1977).

Male mating calls were recorded with a Sony tape recorder (TC-510-2) and a Beyer M88 dynamic microphone, at a tape speed of 19 cm/sec. Wet-bulb air temperatures, mea-

sured close to the calling site of males, and water temperatures were obtained with a Schultheis quick-reading thermometer.

Calls were analysed using a stereo tape recorder (Revox B 7711), a sound spectrograph (Kay Model 6061-B Sona-Graph), a digital processing oscilloscope (Norland 3001/DMX) and a direct recording oscilloscope (Visilight).

Family: HYLIDAE

Cyclorana vaginis Tyler, Davies & Martin, 1981

Material: SAM R23858-61 Newry Sm, N.T., 28 km E of W.A. border, 8.ii.1982.

We located a male and amplexant pair in a shallow pool less than 2 m in diameter surrounded by tall grasses, adjacent to the road. The female had a snout-vent length of 44.4 mm and the two males 43.1 and 45.5 mm respectively. These measurements are within the ranges of the type series (Tyler *et al.*, 1981b).

Before the amplexant pair was formed both males were calling from sites at the edge of the water. Analysis of the mating call is based on

TABLE 1. Intensity of sound at each frequency band within the call of *Cyclorana vaginis* relative to the intensity at the apparent carrier frequency (c. 2500 Hz) based on the formula $I_x = 20 \log$

$\frac{V_x}{V_{ref}}$ where V_x -- peak voltage generated by each frequency band determined from Fourier analysis using a digital processing oscilloscope.

SAM R23860		SAM R23861	
Frequency (Hz)	Relative Intensity (dB)	Frequency (Hz)	Relative Intensity (dB)
820	-1	850	-3
1221	-20	1279	-23
1631	10	1709	-25
2041	+6	2129	-11
2451	0	2549	0
2861	-6	2988	-12
3262	-24	—	—

* Department of Zoology, University of Adelaide, Box 498 G.P.O., Adelaide, S. Aust. 5001.

† Department of Zoology, University of Melbourne, Parkville, Vic. 3052.

detailed examination of one call of each individual; wet-bulb air temperature at the calling sites was 26.0°C. Values for call characteristics of the two males are: duration, 260 and 310 msec; pulse repetition rate, 408–412 and 419–422 pulses/sec; number of pulses, approximately 107 and 130. In both individuals there is a number of frequency bands varying in relative intensity (Table 1). Determination of the apparent carrier frequency, based on oscillographic analysis, shows a shift in frequency during the call of the first male from 2041 to 2564 Hz and in the call of the second male from 2688 Hz to 2564 Hz.

On the basis of these analyses, the complex call of *C. vagitus* (Fig. 1) is best described as a short, regularly-repeated note (call repetition rate 1.15 calls/sec) having a carrier frequency of approximately 2500 Hz, with a number of side bands generated by the modulating frequency of 410–420 Hz (the pulse repetition rate of the call). Presumably, because of the resonating characteristics of the sound-producing structures of the emitter, some of the side bands (particularly those at 820–850 Hz and 2041–2129 Hz; Table 1), together with the carrier frequency, are emphasised.

Family: LEPTODACTYLIDAE

Limnodynastes tasmaniensis Gunther, 1858

Material: SAM R23862–64, UAZ B624, Newry Stn, 33 km E of W.A. border, 8.ii.1982.

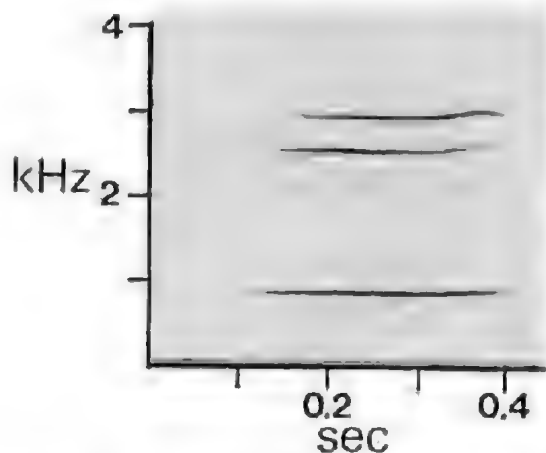


Fig. 1. Audiospectrogram (45 Hz bandpass) of the call of *Cyclorana vagitus* (SAM R23861 Table 1), Newry Stn, N.T., 28 km E of W.A. border. Wet-bulb air temperature at the calling site, 26.0°C.

Small numbers were heard calling from flooded grassland adjacent to the Victoria Highway at sites 24.5–33 km E of W.A. border. We collected specimens only at the eastern end of this transect where a group occupied a flooded depression surrounded by trees. The frogs were breeding and approximately ten freshly-laid foam nests were observed there.

Four calling males were collected. Their snout-vent lengths range 39.2–44.1 mm. All exhibit a bilateral abnormality of the first finger, consisting of a lateral displacement of the terminal portion of the digit.

Martin & Tyler (1978) reported the discovery of an isolated population of this south-eastern Australian species on the northern boundary of the Kununurra township in W.A. They proposed that the species had been introduced accidentally from South Australia beneath transportable homes manufactured at the Adelaide suburb of Pooraka. We cannot propose a similar origin for this N.T. population, because there are no transportable homes at or near the site, and there is no direct contact between Newry Station and South Australia.

The call has been described by Martin & Tyler (1978) as "a short, staccato rattle consisting of 5–7 notes". Values of call components for the single individual recorded at Newry Station generally fall within the range of variation reported by Martin & Tyler (1978). The call consisted of 7 notes with a call duration of 22 msec, a note duration of 10 msec (values for Kununurra individuals ranged from 12–16 msec) and dominant frequency of 1950 Hz; water temperature at the calling site was 26.7°C.

Uperoleia borealis Tyler, Davies & Martin, 1981

Material: SAM R23834, 5.8 km E of Victoria River, 2.ii.1982; SAM R23835, 12.9 km E of Victoria River, 2.ii.1982.

This species previously was known from the northeastern portion of the Kimberley, ranging from Wyndham to Lake Argyle (Tyler *et al.* 1981c). We found specimens only at the above localities which are in the N.T. about 250 km due east of Kununurra, W.A. In addition we heard the species calling at sites 11.2 and 14.7 km E of Victoria River.

Acknowledgments

This field visit was supported in part by an ARGS grant to M. J. Tyler, and was under-

taken under field licence No. 774 issued by the Northern Territory Wildlife Commission.

We are indebted to Dr M. J. Littlejohn and Mr P. Harrison for assistance with call analysis and interpretation, to Mr J. Toner of the Australian National University for the use of facilities at the North Australia Research Unit,

and to the CSIRO Wildlife Research Division for use of a trailer. We thank Mr B. Pennington of Ansett Airlines for assistance with transportation of freight. Finally we thank Simon Fisher for valuable field assistance and companionship.

References

- DINGERKUS, G. & UHLER, L. D. (1977) Enzyme clearing of Alcian blue stained whole small vertebrates for demonstration of cartilage. *Stain Technol.* **52**, 229-232.
- MARTIN, A. A. & TYLER, M. J. (1978) The introduction into Western Australia of the frog *Limnodynastes tasmaniensis*. *Aust. Zool.* **19**, 320-324.
- TYLER, M. J. (1968) Papuan hylid frogs of the genus *Hyla*. *Zool. Verhand.* **96**, 1-203.
- (1976) *Frogs*. (William Collins: Sydney.)
- (1982) *Frogs*, 2nd Edition. (William Collins: Sydney.)
- , DAVIES, M. & MARTIN, A. A. (1981a) Frog fauna of the Northern Territory: new distributional records and the description of a new species. *Trans. R. Soc. S. Aust.* **105**, 149-154.
- , —, & — (1981b) New and rediscovered species of frogs from the Derby-Broome area of Western Australia. *Rec. W. Aust. Mus.* **9**, 147-172.
- , —, & — (1981c) Australian frogs of the leptodactylid genus *Uperoleia* Gray. *Aust. J. Zool.*, Suppl. (79), 1-64.
- , —, & — (1983) Frogs of the Barkly Tableland, Northern Territory. *Trans. R. Soc. S. Aust.* **107**, 237-242.

ON THE STATUS OF SOME NEMATODE SPECIES FROM AUSTRALIAN BIRDS

BY PATRICIA M. MAWSON

Summary

Identification of nematodes from Australian birds, now in progress, has shown that the following nomenclatural changes and comments are necessary.

BRIEF COMMUNICATION

ON THE STATUS OF SOME NEMATODE SPECIES FROM AUSTRALIAN BIRDS

Identification of nematodes from Australian birds, now in progress, has shown that the following nomenclatural changes and comments are necessary.

Comment on *Anisakis diomedae* (Linstow)¹ (Ascaridoiden: Anisakidae): *A. diomedae* was collected from *Diomedea brachyura* in the north Pacific Ocean by the Challenger Expedition. The Challenger material was examined by Baylis² and identified as belonging to the genus *Anisakis* Dujardin, 1845. Since then this species has been placed in *Contracaecum* Ralliet and Henry, 1912, by several authors^{3,4,5}, in *Anisakis*⁶, and in *Anisakis*, syn *Stomachus*⁷.

The most obvious differences between *Anisakis* spp. and *Contracaecum* spp. are the absence of interlabia and of intestinal and oesophageal appendices in *Anisakis*. In *A. diomedae* interlabia and oesophageal and intestinal appendages are absent. There is however a thick ribbon-like excretory canal, one of the features noted by Hartwich⁸ as characteristic of the Anisakinae. This is particularly large in *A. diomedae* and may have been mistaken by some authors (as it was by Johnston, pers. comm. c. 1940) for an intestinal caecum. Johnston and Mawson⁷ give description and figures of the species.

Anisakis is said to occur only in marine mammals^{8,9}. This note is to draw attention to the identity of the species and to the later accounts of Baylis and Johnston & Mawson. It is probable that these are the only authors quoted here who have examined specimens of *A. diomedae*. Further work may lead to the erection of a new genus for the species, but it cannot be considered as belonging to *Contracaecum*.

A. diomedae is very commonly found in albatrosses and petrels from the oceans around Australia.

Proposed nomenclatural changes:

In Heterakoiden: Heterakidae:

Heterakis bancrofti (Johnston)¹⁰ to *Odonterakis bancrofti*. *Odonterakis*¹¹ was erected for Heterakinae in which the spicules are equal and non-alate and in which labial grooves are present. It is distinguished from *Heterakis* by these features and by the presence of three small interlabia. All these features are present in the type material of *H. bancrofti* and in other material from the same host species, so the nomenclatural change is necessary.

Odonterakis spp. have up to the present been recorded only from South American birds, mainly tinamous. The Australian records are mostly from the Brush Turkey, *Alectura lathami*, though there is one record from a Wonga Pigeon, *Leucosarcia melanoleuca*.

In Acuarioiden: Acuariidae:

Acuaria curvica Johnston and Mawson¹², to *A. anthuris* (Rud.)¹³. The appearance and measurements of the single female worm on which the description of *Acuaria curvica* was based are close to those of the numerous specimens of *A. anthuris* now known from *Corvus* spp. from many parts of Australia^{14,15} and the species are considered synonymous.

Echinuria querquedulae Johnston and Mawson¹⁶, to *E. uncinata* (Rud.)¹⁷. *E. querquedulae*, described from a single female from *Anas gibberifrons*, was differentiated from *E. uncinata* mainly by the size of the body spines. It is now considered that this falls within the natural variation in size of spines seen in *E. uncinata* identified from the same and related hosts in Australia¹⁸. Thus *E. querquedulae* becomes a synonym of *E. uncinata*.

¹Linstow, O. von. (1888). Rep. Voyage H.M.S. Challenger 1873-1876 23, 1-18.

²Baylis, H. A. (1923). Parasitology 15, 1-13.

³Johnston, T. H. (1938). Rep. Aust. Antarct. Exped. (1911-1914) Ser. C, 10, 1-31.

⁴Yamaguti, S. (1961). Systema Helminthum, Vol. III, Pt 1 New York. 680 pp.

⁵Davey, J. T. (1971). J. Helminth. 45, 51-72.

⁶Yurke, W. & Maplestone, P. A. The nematode parasites of vertebrates. London, 536 pp.

⁷Johnston, T. H. & Mawson, P. M. (1945). Rep. Brit. Aust. N.Z. Antarct. Exped. Series B 5(2), 73-160.

⁸Baylis, H. A. (1920). Parasitology 12, 253-264.

⁹Hartwich, G. (1974). In C.I.H. Keys to the Nematode parasites of vertebrates. No. 2. R. C. Anderson, A. G. Chabaud, and S. Willmott, Eds. Commonwealth Agric. Bur., Farnham Royal, England. 15 pp.

¹⁰Johnstone, T. H. (1912). J. and Proc. R. Soc. N.S.W. 26, 84-122.

¹¹Skrjabin, K. I. & Schikhobalova, N. V. (1947). Dokl. Akad. Nauk, S.S.S.R. 18, 719-721.

¹²Johnston, T. H. & Mawson, P. M. (1941). Rec. Aust. Mus. 21, 9-16.

¹³Rudolphi, C. A. (1819). Entozoorum synopsis cui accedunt mantissa duplex et indices locupletissimi. Berlin, 811 pp.

- ¹⁴**Mawson, P. M.** (1972). Trans. R. Soc. S. Aust. 96, 139-147.
- ¹⁵**Mawson, P. M., Angel, L. M. & Edmonds, S. J.** unpublished.
- ¹⁶**Johnston, T. H. & Mawson, P. M.** (1942). Trans. R. Soc. S. Aust. 66, 60-70.

PATRICIA M. MAWSON, South Australian Museum, Adelaide, S. Aust. 5000.

LANDSCAPE MODULES FOR EARTH SCIENCE RESEARCH

BY G. G. RILEY AND A. R. MILNES

Summary

Studies of the surficial geology of terrestrial landscapes and the distribution of soils benefit significantly from accurate visual conceptions of the landscapes and landforms. An appreciation of landscape is usually acquired by examining topographic maps and stereographic pairs of aerial photographs in conjunction with observations in the field, but we could only achieve this familiarity in our recent project areas after protracted periods of field work. Consequently, during investigation of the Cainzoic geology and geomorphology of Kangaroo Island, and of the distribution of soils on river terraces flanking the Hindmarsh River on southern Fleurieu Peninsula, South Australia, we developed a simple adaptation of the "layer method" (see for example Coggins & Helford) to construct three-dimensional landscape models with different degrees of topographic exaggeration, based on maps published at various scales.

BRIEF COMMUNICATION

LANDSCAPE MODELS FOR EARTH SCIENCE RESEARCH

Studies of the surficial geology of terrestrial landscapes and the distribution of soils benefit significantly from accurate visual conceptions of the landscapes and landforms. An appreciation of landscape is usually acquired by examining topographic maps and stereoscopic pairs of aerial photographs in conjunction with observations in the field, but we could only achieve this familiarity in our recent project areas after protracted periods of field work. Consequently, during investigation of the Cainozoic geology and geomorphology of Kangaroo Island, and of the distribution of soils on river terraces flanking the Hindmarsh River on southern Fleurieu Peninsula, South Australia, we developed a simple adaptation of the "layer method" (see for example Coggins & Helford¹) to construct three-dimensional landscape models with different degrees of topographic exaggeration, based on maps published at various scales.

Layer-contour models of landscapes and landforms have been widely used^{1,2}, and the method of construction of block diagrams from contour maps is well known. There are sophisticated software packages for depictions of landscapes based on computer technology, but these are not readily accessible nor are they of as much practical use as models constructed by the method we propose because of our requirement for details of locations, geology and other information. The models provide an immediate visual conception of the entire landscape and enhance particular morphological features, depending on the degree of vertical exaggeration utilized. Moreover, selected landforms or sections of the landscape of significance in the particular investigation can be isolated for more detailed examination and illustration by photographing the models from different directions.

Polystyrene foam sheets comprise the basic construction material, together with the published map (topographic map, orthophoto contour map, topographic cadastral orthophotomap, or geological map with topographic data) selected as appropriate for the particular project. Particle board 15 mm thick, cut to the size of the map, is used as the baseboard for the model.

Depending on the vertical exaggeration of relief required for a model of the landscape area under consideration, polystyrene foam sheet of appropriate thickness is chosen to represent the topographic interval on the published map. This choice involves consideration of both the time available for construction of the model and the integrity of the model with respect to the real landscape.

The lowest topographic contour on the map is carefully cut to shape using a small swivelling-

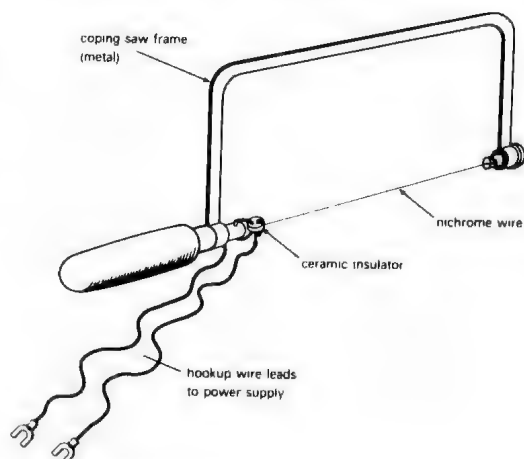


Fig. 1. Hot-wire cutter.

blade scalpel, and the excised map areas below this elevation are glued in place on the baseboard. The remaining portion of the map is positioned on a polystyrene foam sheet and held in place with steel dressmaking pins, and a hot-wire cutter is used to shape the foam sheet accurately along the topographic contour. The cutter (Fig. 1) is constructed from a coping-saw frame, with the blade replaced by 0.4 mm nichrome wire insulated from the frame by a ceramic bead. Two lengths of hook-up wire connect the handle end of the saw frame and the insulated end of the nichrome wire to a current-controlled DC power supply. A current of 1A at 3V heats the nichrome wire sufficiently to cut and seal the foam sheet cleanly and accurately: the foam decomposes if the wire temperature is too high. The resulting template, with the map removed, is glued to the baseboard. A water-based latex glue is necessary because polystyrene is dissolved by most glues with an organic solvent base. Dressmaking pins are used to hold the foam template in place until the glue sets.

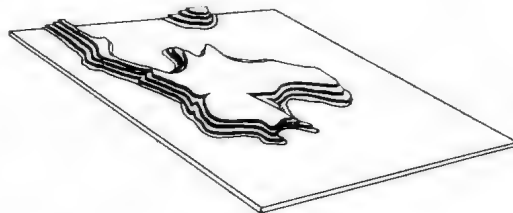


Fig. 2. Relief model in process of construction with templates representing successively higher topographic contours glued in position.

The next highest topographic contour on the map remnant is then carefully cut out using the swivelling-blade scalpel, producing a thin map strip: this is glued into position on the margins of the polystyrene foam template. The new map remnant is pinned in place on a sheet of foam, and the second template is made and glued in position. The relief model (Fig. 2) grows as the steps are repeated. With the map strips glued in place, the model incorporates all the information contained within the original map sheet, including details of location and other geographic or geologic features. Alternatively, the final product may be a simple relief model without the superimposed map information.

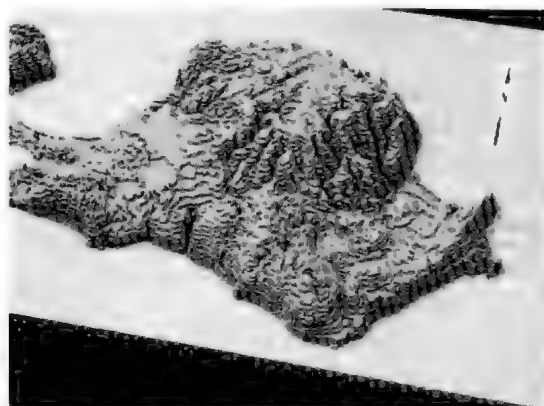


Fig. 3. Simple relief model of Dudley Peninsula, Kangaroo Island. Horizontal scale 1:50 000.

Four of the several models constructed during our research studies are illustrated here. The model of Dudley Peninsula on Kangaroo Island (Fig. 3) is one of simple relief at 1:50 000 horizontal scale with a vertical exaggeration of 25 times. It has been used as a guide for determining the distribution of Cainozoic marine sediments and associated calcretes in relation to the high-level, deeply weathered and ferruginised plateau region in the north.

At 1:2500 scale and with a vertical exaggeration of about 6 times, the model of the lower reaches of the Hindmarsh River on southern Fleurieu Peninsula (Fig. 4) illustrates well the various alluvial terraces in relation to the adjacent low hills. The model is used as a guide for interpreting the evolution of the terraces and the distribution of various soil types on them.

Constructed from a geological map with topographic data, the model of the Encounter Bay area (Fig. 5) illustrates the distribution of Permian-Carboniferous glaciogenic sediments in valleys cut into Cambrian granites and metasediments. Quaternary sediments occupy the modern lowlands, and deep-weathering profiles with associated

zones of ferruginisation mantle the bedrock and the Late Palaeozoic glaciogenic sediments in highland areas on the western side of the model.

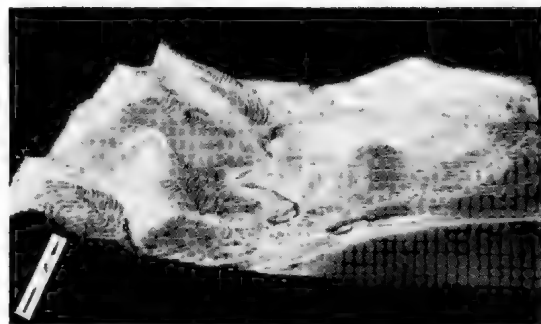


Fig. 4. Relief model of lower reaches of Hindmarsh River, southern Fleurieu Peninsula, South Australia, at 1:2500 horizontal scale. Model has superimposed topographic cadastral orthophotomap.

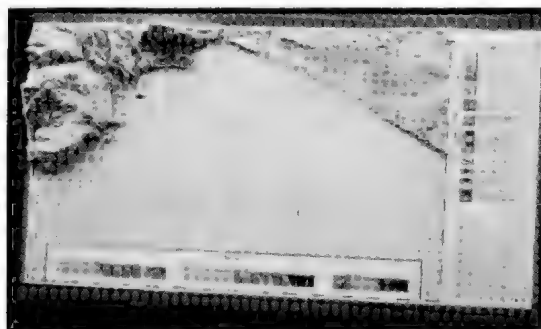


Fig. 5. Relief model of Encounter 1:63 360 geological map sheet.

Using a cadastral map at 1:10 000 horizontal scale, a relief model with 10 times vertical exaggeration was constructed of part of the MacDonnell Ranges and adjacent Todd River Plain southeast of Alice Springs (Fig. 6). In order to model the steep ridges of Heavitree Quartzite constituting the ranges, it was necessary to use 25 mm thick polystyrene foam sheet to represent 25 m contour intervals at elevations above 575 m. The resulting model illustrates clearly the distribution of mesas with siliceous duricrust caprock along the southern margin of the ranges, and provides the basis for interpretation of the mesas as remnants of an ancient piedmont landscape.

Despite their obvious limitations, we have found the models to be invaluable, not only in presenting observations in the manner of the CSIRO Land Research Series, but as research tools in gaining rapid appreciation of the morphology of the areas being examined, in studying the relationships of pedological and geochemical data

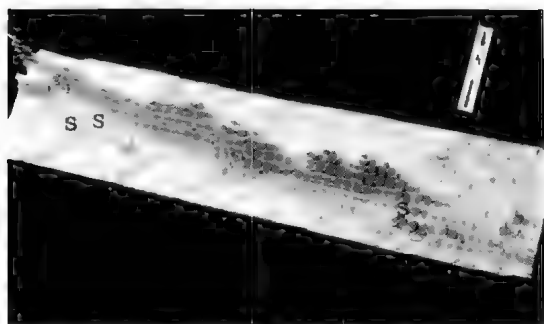


Fig. 6. Relief model at 1:10 000 horizontal scale of Emily, Jessie and Undoolya Gaps in MacDonnell Ranges southeast of Alice Springs. Mesas with siliceous duricrust caprock are marked "S".

with landscape morphology, and in generally facilitating discussions of field relationships back in the laboratory. The method of construction is not particularly time-consuming, but necessitates careful inspection of the map being modelled, so that detailed features may be noted that might otherwise have been overlooked.

In the light of the availability of improved contour maps, including the large-scale orthophotomap, we consider that our method for constructing reasonably accurate landscape models has much to commend it to research workers in earth and environmental sciences.

We thank Richard May for preparing the model of the Encounter Bay area, John Coppi for the photographic work, and G. Blackburn for constructive comments on the manuscript. The Publications Group at CSIRO Division of Soils prepared the diagrams.

¹Coggins, R. S. & Hefford, R. K. (1966). "The Practical Geographer" 2nd Ed. (Longmans: Melbourne).

²de Laine, R. J. & Clarke, N. (1964). *Aust. Geogr.* 9, 235-236.

G. G. RILEY and A. R. MILNES, CSIRO Division of Soils, Private Bag No. 2, Glen Osmond, S. Aust. 5064. R. P. BOURMAN, Waite Agricultural Research Institute, University of Adelaide, Private Bag No. 1, Glen Osmond, S. Aust. 5064.

Errata

Trans. R. Soc. S. Aust. 107(2), 137, 31 May, 1983.

Replace with the following:

Line 8, col. 1: "endangered species², is how . . ."

Lines 3-8, col. 2: $y = 0.19 \pm 0.0005x$, $r^2 = 0.92$, $n = 30$, $p < 0.001$
 $y = 0.19 \pm 0.0003x$, $r^2 = 0.96$, $n = 96$, $n = 14$, $p < 0.001$
 $y = 0.08 \pm 0.0006x$, $r^2 = 0.98$, $n = 17$, $p = < 0.001$

Line 46, col. 2: "to 300 ha sheep⁻¹ or lighter . . ."

RED-BROWN HARDPANS AND ASSOCIATED SOILS IN AUSTRALIA

BY M. J. WRIGHT

Summary

Here I clarify the position regarding those hardpans in the surficial mantles of the Australian arid zone that qualify for the preferred informal name “red-brown hardpan”. Descriptions are remarkably uniform and refer to a typically red to red-brown (2.5YR 4/6-4/8 or 5/6-5/8, moist) vesicular indurated material, extremely hard both wet and dry. Structure is usually strong but irregularly platy, or may be blocky. Black manganiferous accumulations are characteristic and occur on the surface and within peds. Irregular vertical partings often occur; secondary carbonate, where present, coats these and aggregate faces, but may be absent within peds. Fracture and cleavage faces usually have a dull porous earthy appearance.

RED-BROWN HARDPANS AND ASSOCIATED SOILS IN AUSTRALIA

Here I clarify the position regarding those hardpans in the surficial mantles of the Australian arid zone that qualify for the preferred informal name "red-brown hardpan"¹. Descriptions are remarkably uniform and refer to a typically red to red-brown (2.5YR 4/6-4/8 or 5/6-5/8, moist)² vesicular indurated material, extremely hard both wet and dry. Structure is usually strongly but irregularly platy, or may be blocky. Black manganese accumulations are characteristic and occur on the surfaces and within peds. Irregular vertical partings often occur; secondary carbonate, where present, coats these and aggregate faces, but may be absent within peds. Fracture and cleavage faces usually have a dull porous earthy appearance.

Similar materials are known to occur in arid areas elsewhere; in S. Africa³ they are known as "dorbanks", while Soil Taxonomy⁴ terms them "duripans". In Australia they have been the subject of pedological studies since 1937⁵ when the Great Soil Group "red and brown hardpan soils" was proposed. Despite the fact that a genetic relationship between soil and hardpan has never been established adequately, Stage *et al.*⁶ retained this group in 1968 and included in it all arid zone hardpans and associated soils. They did, however, concede⁶ that in some occurrences hardpan may have formed in older soil stripped before deposition of younger material. Their Great Soil Group approach has a further weakness in that it does not entertain the possibility of different cementing agents and ages of formation for similar hardpans. It will be demonstrated, in support of this criticism, that as experience has increased, so has the number and variety of soils that occur on red-brown hardpan.

In S. Aust., at least, geologists appear to have ignored hardpans until recently⁷ apart from recording them as a member of beds or formations⁸. While they have been reported from many localities in the Australian arid zone and variously named seldom are enough data presented to allow even tentative correlation; nor is the cementing agent usually established beyond doubt though silica is often implied. These materials lacked a formal name until Jessup & Wright⁹ named the Illeruo Pedoderm (characteristically containing a hardpan) in S.A. and Bettenay & Churchward¹⁰ the Wiluna Hardpan in W.A.

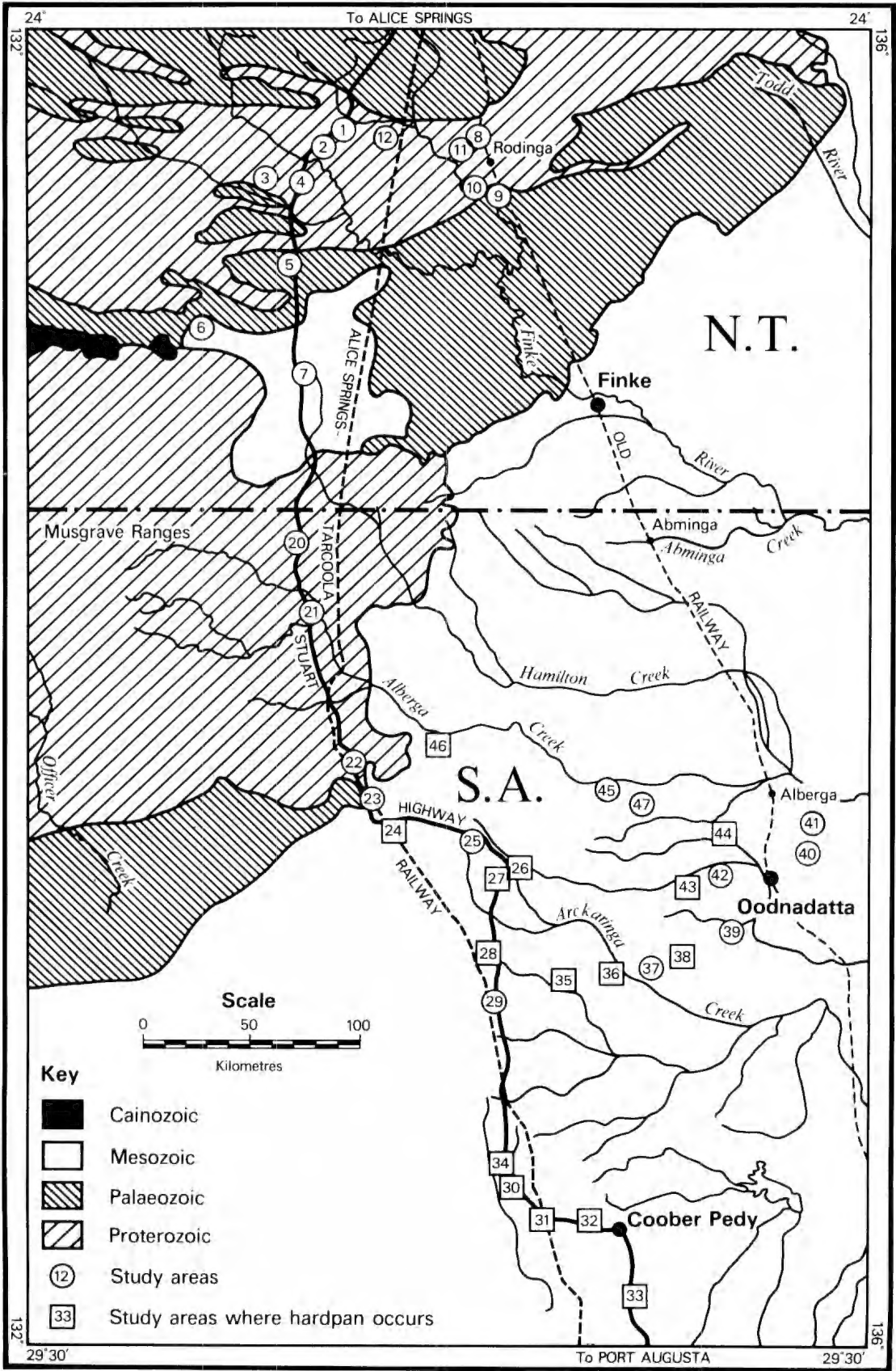
Perhaps the most definitive studies are those of Litchfield & Mabbitt¹¹ and Bettenay & Churchward¹⁰ in W.A. Bettenay & Churchward formally named the Wiluna Hardpan and with Brewer¹² suggested that the principal cementing agent is

silica, although impregnation by iron oxides and calcium carbonate was apparent at different sites. Wiluna Hardpan appears the most widespread occurrence of red-brown hardpan but Bettenay & Churchward were unable to assign it an absolute age¹⁰; they stated that it may have developed during the Late Tertiary or Early Quaternary. They observed that the hardpan usually occurs in alluvium and colluvium on surfaces either carved out of, or enveloping, the lower parts of the "laterite-mantled landscape". Another hardpan, known locally as "Murchison cement", occurs in younger alluvia; from this they concluded that modern development of hardpan is not precluded in areas of suitable climate and topography.

Litchfield & Mabbitt¹¹ had studied the Wiluna Hardpan and used chemistry and micromorphology to determine that the cement consisted of layered argillans/silans, i.e. clay deposition preceding that of silica. They concluded that soil drainage was a significant factor in determining the depth to hardpan (hardpan was deeper under sandy soils), and that hardpan did not occur beneath "grumusolic" (cracking clay) soils in gilgai depressions. They did not specify an age, presumably because they accepted that the hardpan was currently forming in the "youngest alluvia".

In western N.S.W., Lawrie¹³ studied occurrences of hardpan along 100 km of gas pipeline trench. He accepted that this hardpan had the same basic construction as the Wiluna Hardpan on the basis of treatment with HCl and HF. Like Litchfield & Mabbitt¹¹ he found that it was absent beneath cracking clay (Ug5) soils in gilgai depressions, and that depth of formation was controlled by the texture and nature of the overlying soil.

In nation-wide mapping of Australian soils, Northcote *et al.*¹, drawing on all earlier soil studies, recorded 9 principal profile forms (PPF, Northcote¹¹) occurring on red-brown hardpans. Lawrie¹³ increased this number to 26: current soils work on 40 study areas between Coober Pedy and Alice Springs (Fig. 1) shows red-brown hardpan is even more widespread than recorded¹ and adds a further 14 PPF. These range from extremely shallow loam (Um1) soils to moderately deep cracking clay (Ug5) soils. This field evidence alone strongly suggests that the hardpans are not directly related to any of the soils occurring above them. In fact, hardpan is found to occur, not only beneath as little as 10 cm of loamy soil, but also as shallow as 50 cm beneath cracking clay (Ug5) soils in gilgai depressions, in direct contrast to the situations quoted^{11,13}.



In recent geological mapping by Benbow⁷ in the Coober Pedy area, a hardpan has been named "Coober Pedy Paleosol". It occurs within Giddinna Formation, correlated with the upper member of the previously named Russo Beds⁸. Furthermore, a thin hardpan is described within Benitos Clay, overlying Giddinna Formation, but this description is inadequate. An early Late Pleistocene age is assigned to the Coober Pedy Paleosol, and a later Late Pleistocene age to Benitos Clay⁷. The description of the Coober Pedy Paleosol fits that of red-brown hardpan, which in the present study areas appears to occur exclusively on Mesozoic rocks (Fig. 1) or their detritus (whether alluvial or colluvial). However, a different hardpan (presumably younger) that may correlate with the material described as hardpan in Benitos Clay⁷ was observed in alluvium flanking Alberga Creek.

North of Whyalla, Jessup & Wright⁹ found a red-brown hardpan (in Illeroo Pedoderm) which they considered to be an indurated soil. It was subsequently traced northwards from Kingoonya to Coober Pedy¹⁰. Despite extensive chemical and micromorphological examination, they were unable to establish any definite cementing agent. Compound joint plane argillan/calcanes, in some instances, and zones of strongly oriented clay in others, may be responsible for induration. Certainly, none of the samples collected could be dispersed by normal methods.

It is apparent from the viewpoints of stratigraphy and soil taxonomy that hardpans and their "related" soils need definitive study. Some of the questions currently being studied are:

1. Can hardpans be distinguished from, or related to, each other and used confidently as stratigraphic markers? 2. What is the principal cementing agent in each of the hardpans? 3. Are there secondary cementing agents? 4. If cementing agents differ, do such differences relate to age, to position in the landscape, or to soil weathering environments? 5. Are hardpans paleosols, cemented sediments, or both? 6. Are red-brown hardpans currently forming? If so, what are the environmental conditions necessary for their formation?

At present one has to speculate for want of critical evidence. However, current observations support the view that formation of red-brown hardpans has been episodic, commencing perhaps in the Late Tertiary. While contemporary formation cannot be ruled out, it is likely to be extremely localised, confined to pockets where suitable conditions prevail.

The informal name *red-brown hardpan* is preferred because, at least from the pedological viewpoint, it recognises the hardpan as an entity distinct from most soils. While this might be a gross oversimplification, it is nevertheless more realistic at the present state of knowledge than the Great Soil Group name⁶, red and brown hardpan soils. The Factual Key of Northcote¹¹ is also ambiguous with regard to the definition of soils and soil associations based on the presence of hardpan as a diagnostic horizon. It is imperative that current research on hardpans clarifies these problems.

⁷Northcote, K. H., with Beckmann, G. G., Bettenay, E., Churchward, H. M., Van Dijk, D. C., Dimmock, G. M., Hubble, G. D., Isbell, R. F., McArthur, W. M., Murtha, G. G., Nicolls, K. D., Paton, T. R., Thompson, C. H., Webb, A. A., & Wright, M. J. (1960-68). Atlas of Australian Soils, Sheets 1-10 with explanatory data. (CSIRO and Melbourne Univ. Press).

⁸Munsell Soil Color Charts (1975 ed.) (Munsell Color; Baltimore, Maryland, U.S.A.)

⁹Muevcar, C. N., De Villiers, J. M., Loxton, R. F., Verster, E., Lambrechts, J. J. N., Merryweather, F. R., Le Roux, J., Van Rooyen, T. H., & Von M. Harmse, H. J. (1977). Soil Classification. A binomial system for South Africa. Science Bulletin 390. (Dept. Agric. Tech. Services).

¹⁰U.S.D.A. Soil Survey Staff (1975). U.S.D.A. Agric. Handbook No. 436. 745 pp.

¹¹Teakle, I. J. H. (1937). J. Dept. of Agric. W.A. 13, 480-493.

¹²Stace, H. C. T., Hubble, G. D., Brewer, R., Northcote, K. H., Sleeman, J. R., Mulcahy,

M. J., & Hallsworth, E. G. (1968). A Handbook of Australian Soils. (Rellim).

¹³Benbow, M. C. (compiler) (1981). COOBER PEDY map sheet. Geological Atlas of South Australia, 1:250,000 series, geol. Surv. S. Aust. and explanatory notes Rept. Bk No. 80/153.

¹⁴Barker, I. C., Barnes, I. C. & Benbow, M. C. (1979). Q. geol. Notes, geol. Surv. S. Aust. 71, 2-7.

¹⁵Jessup, R. W. & Wright, M. J. (1971). Geoderma 6, 275-308.

¹⁶Bettenay, E. & Churchward, H. M. (1974). J. geol. Soc. Aust. 21, 73-80.

¹⁷Litchfield, W. H. & Mahbutt, J. A. (1962). J. Soil Sci. 13, 148-159.

¹⁸Brewer, R., Bettenay, E. & Churchward, H. M. (1972). CSIRO Aust. Div. Soils Tech. Pap. 13.

¹⁹Lawrie, J. W. (1978). Proc. First Int. Rangeland Congr. pp. 303-306.

²⁰Northcote, K. H. (1979). A Factual Key for the Recognition of Australian Soils. (Rellim).

²¹Jessup, R. W. & Norris, R. M. (1971). J. geol. Soc. Aust. 18, 303-331.

ROYAL SOCIETY OF SOUTH AUSTRALIA INCORPORATED

Patron:

HIS EXCELLENCY THE GOVERNOR OF SOUTH AUSTRALIA
LIEUTENANT-GENERAL SIR DONALD DUNSTAN, K.B.E., C.B.

OFFICERS FOR 1983-84

President:

J. S. WOMERSLEY, B.Sc

Vice-Presidents:

D. W. P. CORBETT, B.Sc., Ph.D.

M. J. TYLER, M.Sc.

Secretary:

P. M. TAYLOR, B.Sc.

Treasurer:

R. H. FISHER, A.U.A.

Editor:

M. DAVIES, M.Sc.

Assistant Editor:

A. R. MILNES, Ph.D.

Librarian:

N. P. McKELLAR-STEWART,
B.Sc., Dip.Lib.

Programme Secretary:

W. G. BREED,
B.Sc., D.Phil.

Minute Secretary:

R. J. SHIEL, B.Sc., Ph.D., T.S.T.C.

Membership Secretary:

P. M. THOMAS, M.Sc.

Members of Council:

K. H. NORTHCOTE, B.Ag.Sc., D.Sc.
D. C. LEE, M.Sc.

C. J. M. GLOVER, J.P., M.Sc.
C. B. WELLS, E.D., M.Ag.Sc.

R. B. FLINT, B.Sc.

Auditors:

STEVENS, SEARCY, HILL & CO.